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Enhancing Access at the Tower of London

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Historic Royal Palaces

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Abstract

The Tower of London is a 1000-year-old fortress with many access challenges for D/deaf and disabled visitors. The purpose of this project was to enhance access through non-traditional means using digital technologies. We performed background research, distributed a survey, and conducted accompanied tours to help us determine the best technologies to increase access. From our findings we recommend 3D printed models, Signly, and Virtual Reality be implemented at the Tower. The implementation of these recommended technologies at the Tower of London would greatly improve accessibility for D/deaf and disabled individuals.

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Executive summary

The Tower of London is a 1000-year-old fortress, palace, and prison. The Tower was designed to be difficult to enter and harder to escape. Spiral staircases, uneven surfaces, and narrow doorways pose access challenges for D/deaf and disabled visitors at the Tower. In the United Kingdom 19% of people identify as disabled; however, only 59% of people rated museums and art galleries as 'good' for accessibility (Smith, 2017; Vocaleyes, 2016). The Tower of London would like to increase accessibility for disabled individuals but traditional methods of improving access can be difficult to implement due to the historic nature of the Tower. For this reason, Historic Royal Palaces would like to explore the possibility of implementing digital technologies to improve accessibility for disabled visitors at the Tower.

Our goal for this project was to evaluate how digital technologies can help HRP increase accessibility for D/deaf and disabled visitors at the Tower of London. To complete this goal, we identified five main objectives:

1. Perform market research to assess digital technologies used to broaden access in the museum and heritage sectors and assess emerging technologies that could be applicable in the future.
2. Assess the current state of accessibility at the Tower of London for the D/deaf and disabled communities.
3. Assess stakeholder opinions in the D/deaf and disabled communities regarding the use of technology to promote greater accessibility.
4. Evaluate the viability of implementation of current and potential technologies to promote greater access at the Tower of London.
5. Recommend how HRP might improve accessibility at the Tower of London using digital technologies.

We began by researching digital technologies currently used for accessibility as well as technologies that could be used to increase access. We toured the Tower of London multiple times in search of access challenges. Additionally, we analyzed the Access Review of the Tower of London to isolate which challenges were most common as well as which ones we thought could be fixed with digital technologies. We also researched and visited the most accessible museums and historical sites in the United Kingdom to find out what technologies they use. We met with representatives from Hampton Court Palace, the British Museum, Graeae Theatre, and

the Roald Dahl Museum and Story Center. These visits helped us narrow our list of potential digital technologies based on feedback the museums have received. Additionally, these organizations introduced us to some technologies of which we were unaware. With the help of Graeae Theatre, we developed a survey to understand the current state of access at the Tower as well as technology preferences among disabled people. Graeae was instrumental in our efforts to make the survey as accessible and sensitive as possible. After we completed these site visits, we conducted six accompanied tours with visitors with various disabilities. Each of these visits lasted approximately two hours and was followed by a short interview. We asked visitors to explain some of the access barriers they encountered on their visit and describe their overall impression of accessibility during their visit. We also asked what technologies they thought might have improved their visit. These accompanied tours were tremendously helpful to us in deciding the best digital technologies for implementation by allowing us to understand the access challenges present at the Tower.

Through our research we found that there is a diverse range of preferences on assistive technology. We used the results from our survey and accompanied tours to produce a number of recommended digital technologies to enhance access at the Tower. From our research, we found that 3D printed models, Signly, and Virtual Reality best address the current access needs at the Tower of London. Additionally, there are a few developing technologies that we suggest Historic Royal Palaces monitor moving forward. We also compiled a list of non-digital technologies to be used in conjunction with the suggested digital technologies to increase accessibility at the Tower.

Authorship Table

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1. Introduction

11.9 million people in the United Kingdom (U.K.) have a disability, according to Smith's 2016 report. Of these 11.9 million people, 57% have a mobility impairment, 38% have decreased stamina, 28% have limited dexterity, and 16% have mental health condition (Smith, 2017, p. 5). Due to the large number of individuals with various disabilities the Government of the United Kingdom has made an effort to make public buildings and attractions more accessible for all. For example, the U.K. Government passed the Equality Act of 2010 which spurred accessibility reform. Due to this movement, museums in London and elsewhere in the U.K. are attempting to improve access for disabled individuals. Unfortunately, as documented in the 2015 Access Survey, museums and art galleries were reported as having good accessibility by only 59% of disabled people (VocalEyes, 2016). Historic Royal Palaces (HRP) is striving to improve access at all its facilities, but HRP faces greater challenges because it cannot easily make physical changes to structures, like the Tower of London, that are protected historical and cultural sites. Staff at the Tower of London are therefore particularly interested in exploring the use of digital technologies that offer the possibility to enhance access without damaging or substantially altering the physical infrastructure.

The goal of this project is to evaluate how digital technologies can help HRP increase accessibility for D/deaf and disabled visitors at the Tower of London. This project has five main objectives. We will: (1) perform market research[1] to assess digital technologies used to broaden access in the museum and heritage sectors and assess emerging technologies that could be applicable in the future; (2) assess the current state of accessibility at the Tower of London for D/deaf and disabled visitors; (3) assess stakeholder opinions in the D/deaf and disabled communities regarding the use of technology to promote greater accessibility; (4) evaluate the viability of implementation of current and potential technologies to promote greater access at the Tower of London; and (5) recommend how HRP might improve accessibility at the Tower of London using digital technologies.

To accomplish our objectives, we conducted an online survey and in person interviews with disabled individuals. We also interviewed staff at museums that have implemented innovative approaches to enhance accessibility, including the use of digital technologies. We

[1] In the context of this project market research refers to research of available digital technologies.

used the results of our research, interviews, and survey to make recommendations to HRP as to what digital technologies could help improve access at the Tower of London.

2. Background

In the United Kingdom, approximately one fifth of the population is D/deaf or disabled (Smith, 2017, p. 34). These individuals are protected by the U.K. Government under the Equality Act of 2010 (Centre, n.d.b). Historic Royal Palaces strives to increase accessibility for disabled individuals in accordance with their mission statement, but HRP has faced challenges because of the historical status of the Tower of London. A variety of currently available and emerging technologies could improve accessibility at the Tower. HRP would like to implement digital technologies to create a more inclusive environment for disabled individuals.

2.1 Disabilities in the United Kingdom

People may have numerous disabilities which range from physical and mental disabilities to being on the autism spectrum. With the advice of our sponsors, we chose to focus on mobility impaired, vision impaired, hard of hearing and D/deaf visitors for our project. These are the groups that our sponsor saw the most potential to help with our project so we have chosen to focus our efforts here. Historic Royal Palaces wants to learn about digital technologies that other museums use to improve accessibility.

2.1.1 The social model of disability

There are two common models for describing disabilities: the medical model and the social model. The medical model views impairments as a condition that can be treated in order to help individuals overcome challenges. Some members of the disabled community oppose this view because it implies that the impairment is inherently a disability. The social places more concentration on society's inaccessibility rather than on the individual with the impairment. For example, under the social model, ramps should be installed at locations where stairs could prevent an individual with a mobility impairment from entering. The medical model would attempt to find a way to help the person walk instead (The social model of disability, n.d.). The difference between the way the disability is viewed is the most fundamental difference between the social model and the medical model.

The social model of disability took shape in the 1970s and has driven reform, in areas such as making reasonable accommodations for disabled people (Samaha, 2007). The social model places responsibility on society through the language it uses to describe disabilities. The

main difference in the language used by the medical model and social model is that the medical model advocates the use of person first language. Under the medical model the accepted language to refer to a disabled individual is an individual with a disability. The medical model uses these phrases because the focus is on the person rather than the disability. However, with the social model, the preferred language is disabled person or disabled individual. Additionally, when discussing a medical condition, the social model says that it should be referred to as an impairment rather than a disability (Davis, 1996). The language used to describe disabled people is a topic of debate. The social model argues that the medical model and person first language place too much focus on fixing the disability rather than making accommodations for the disabled individual.

Not all disabled people agree with the social model of disability. One argument against the social model is that it focuses too much on how disabilities are viewed rather than the rights of the disabled people (Smith, 2013). Additionally, some members of disabled communities perceive the social model as a form of oppression due to the focus on society rather than helping the individual. The diversity of disabled communities also provides a challenge to the social model. Due to the diverse needs of so many individuals, opponents of the social model believe that it is impossible for a location to be made completely accessible (Owens, 2014). The social model faces criticism but remains the best-practice way of viewing disabilities.

2.1.2 British Sign Language

There is a common misconception that British Sign Language (BSL) is another version of English while in fact, they are different languages with completely different syntax. For people who started signing at a young age, BSL is often considered their first language, while English is their second. For D/deaf children, by age 18, their reading level is often comparable to a year four or five hearing student (*Reading Research & Deaf Children*, 2011). This low reading level means that D/deaf people may struggle with reading and understanding large blocks of text, especially at museums where they may be expected to read this information quickly due to large crowds. For this reason, it is important that as much text information as possible is available in BSL.

2.1.3 Demographics of the disabled community

Smith (2017) compiled data from a variety of official sources stating the U.K. disability demographics. Smith indicated that, "In 2014/15, the most common impairments that disabled people had were: mobility (57%), stamina/breathing/fatigue (38%), dexterity (28%) and mental health (16%)" (Smith, 2017, p. 5). Due to the large percent of mobility impaired individuals, mobility impairments are one the disabilities that we chose to focus on for this project. He found that in 2016, the U.K. reported that there were 11.9 million disabled people, which is about 19% of the United Kingdom's population (p. 5). This figure has remained constant over time with a similar amount of people having a disability over many years. Smith reported that in March 2014, there were 143,400 people registered as blind (p. 34). 10 million people in the United Kingdom have some form of hearing loss (p. 35). The percentage of disabled people in the U.K. increases with age for all disability types, including hearing, vision, and mobility impairment (Smith, 2017). Data on disabilities is hard to collect because different organizations use different definitions of disability. The data above is from the Department of Work and Pensions. When visiting the arts, heritage sectors, museums, galleries, and libraries, when compared to non-disabled people, disabled people had a lower engagement rate in 2013/14 (p. 39). The lower engagement rate could be due to difficulties in transportation to these facilities or difficulties in receiving the proper accessibility technologies, such as hearing loops, that would allow them to better engage with the exhibits (Smith, 2017, p. 40).

Unfortunately, given the large number of people who are D/deaf and disabled, many museums and heritage sites still struggle to provide appropriate access to buildings and exhibits. There is no comprehensive data on the number of museums and heritage sites that are accessible, but a recent survey found only 18% of museum websites indicate that they are welcoming of disabled visitors (VocalEyes, 2016). According to the 2015 Access Survey, only 59% of disabled people found museums and art galleries to have 'good' accessibility. In addition, 95% of respondents stated, "that they have tried to find disabled access information about a venue before visiting it and 54% [stated] that they avoided going to new places if they could not find relevant access information" (VocalEyes, 2016). Part of the reason that people believe museums are inaccessible is because only 18% of museums publicize their labels and information in large print (Blind and partially sighted people missing out on museums due to lack of accessible information, 2016). Due to the large population of disabled people in the United Kingdom,

museums, including the Tower of London, are committed to promoting accessibility using digital technologies, but they still have a long way to go.

2.1.4 Equality Act 2010

The U.K. government defines disability as "a physical or mental impairment that has a 'substantial' and 'long-term' negative effect on your ability to do normal daily activities" (Definition of disability under the Equality Act 2010, n.d.). According to the Equality Act 2010, a disabled individual may not be discriminated against because of their disability when being considered for employment, education, or when dealing with police (Office for Disability Services HM Government, 2011). In addition to the act containing language preventing discrimination, the Equality Act also has a section titled Duty to Make Adjustments. The Equality Act states that adjustments must be made for individuals who would be put at a disadvantage without the provision. This section also states that each person must make accommodations for disabled individuals so long as the changes are reasonable (Equality Act 2010, n.d.). The U.K. government determines an adjustment to be reasonable if it is practical, the cost of the adjustment is feasible, the size of the organization is deemed adequate, and if an accommodation has not already been made (Duty to make reasonable adjustments for disabled people, n.d.). Historic Royal Palaces would like to go above and beyond reasonable adjustments; however, HRP faces many challenges because of the historical status of the Tower of London.

2.2 UNESCO restrictions on the Tower of London

UNESCO recognizes the Tower of London as a cultural site and aims to preserve the structure of the Tower of London by partnering with the U.K. government. The U.K. government recognizes the Tower of London as a scheduled monument and places the Tower under the protection of the Ancient Monuments and Archaeological Areas Act of 1979 (Centre, n.d.b). The Ancient Monuments and Archaeological Areas Act of 1979 imposes strict restrictions on the types of alterations that can be made to the Tower of London, even if the proposed changes are in the interest of accessibility. These restrictions include no demolition, destruction, damage, removal, repair, alteration, or additions to a scheduled monument, and no flooding or tipping[2]

[2] Tipping - the use of a machine which holds a substance such as dirt or gravel in a bucket then by motion of a bucket drops the substance (Olesa, n.d.).

operations may be performed at a scheduled monument. Due to the Ancient Monuments and Archaeological Areas Act of 1979, HRP cannot make any structural changes to the Tower of London (Ancient Monuments and Archaeological Areas Act 1979, n.d.).

2.3 Current accessibility at the Tower of London

Historic Royal Palaces was founded in 1998 as a non-profit organization (About Us, n.d.; Historic Royal Palaces, 2018). HRP welcomes approximately four million visitors to their sites each year, with approximately 63 percent of those visitors going to the Tower of London, as pictured in Figure 1 below (*Annual Review 2016/17* (Rep.), 2017). Appendix A gives additional information about HRP.

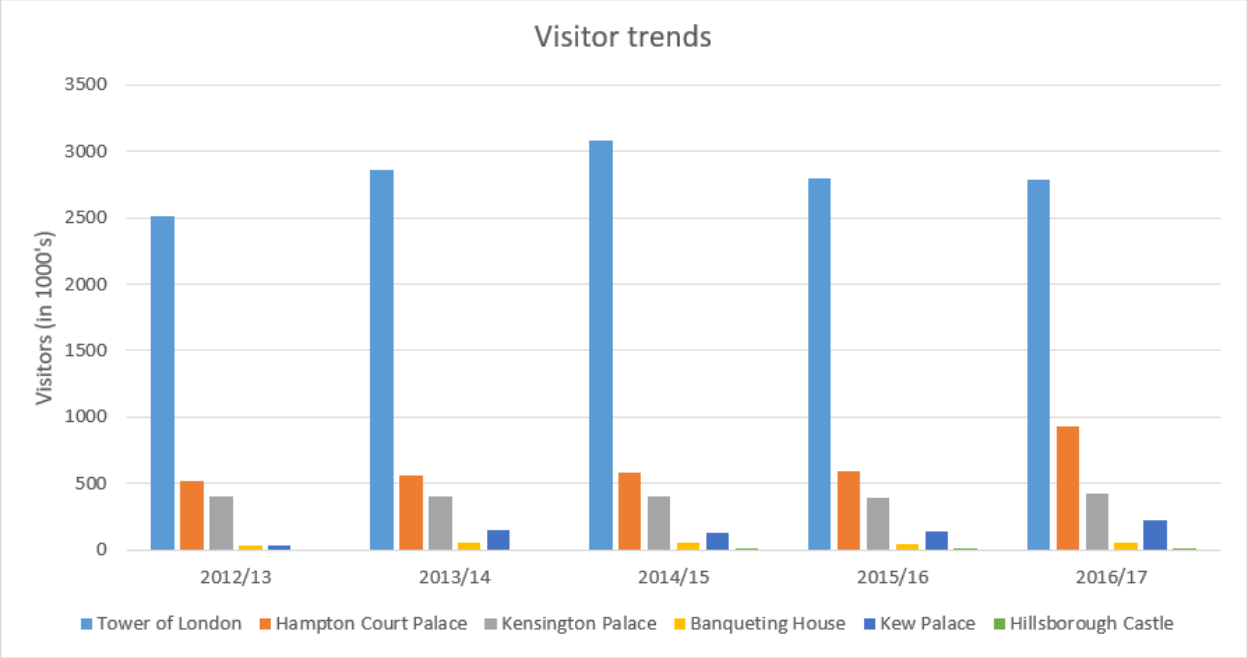

Figure 1: Visitation trends at HRP properties 2012-2017 fiscal years (*Annual Review 2016/17*)

The HRP and Tower of London are striving to improve access and comply with the Equality Act, but this is difficult to do given the nature of the site and restrictions of UNESCO. HRP currently provides British Sign Language tours, areas with tactile displays, and information in braille in the basement of the White Tower (Accessibility, n.d.). HRP and the Tower are constantly evaluating ways to improve accessibility for disabled visitors and have conducted and Access Review that outlines strategies for solving these problems.

The Tower of London has long, winding staircases and narrow pathways with cobbles that make access difficult. Figure 2 shows an example of a spiral staircase at the Tower of London. Tourists can only view 20% of the Tower without having to use stairs (Sage Traveling, PR Executive at Sage Traveling Follow, 2012). Accessing the Crown Jewels, which are located in the only step-free exhibiton at the Tower of London, is difficult because it entails walking over two hundred meters of cobblestone and walking up a 200-meter smooth hill. Figure 3 provides a map of the step-free path and Figure 4 shows the cobblestone walkways. The main part of the Tower of London has limited space, with approximately 250 steps, low doorways, and cobblestones laid in some of the surfaces. Figure 5 provides a map of the Tower of London which highlights the areas with access challenges (Sage Traveling, PR Executive at Sage Traveling Follow, 2012). In order to protect the historical site and prevent accidents from happening, many passageways have been closed to the public.

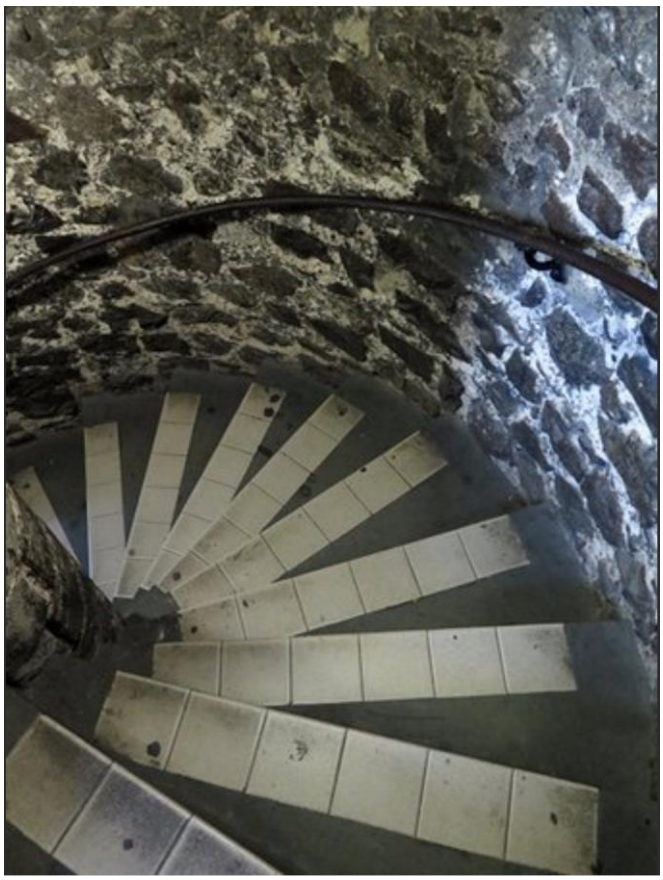

Figure 2: Staircase in the White Tower at the Tower of London (TripAdvisor, n.d.a)

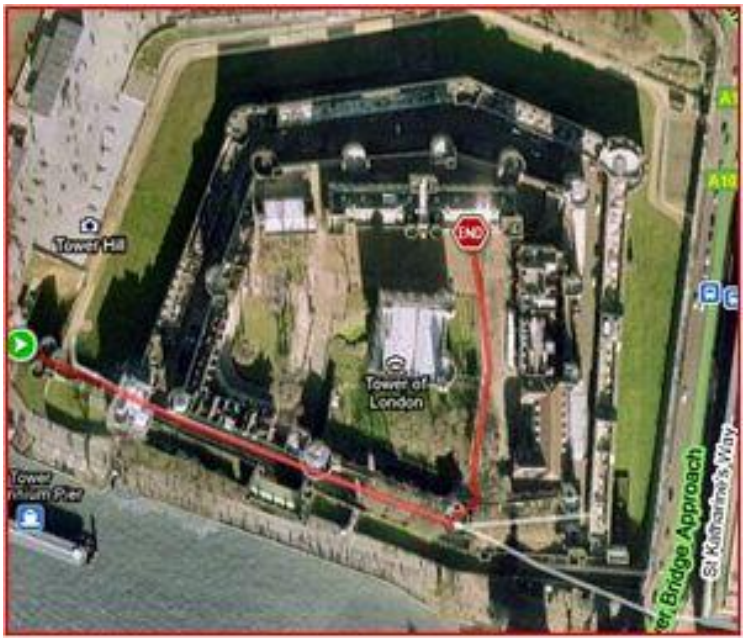

Figure 3: Step-free accessible route to the Crown Jewels (Sage Traveling, n.d.)

Figure 4: Cobblestone walkways impair access (Tripadvisor, n.d.b)

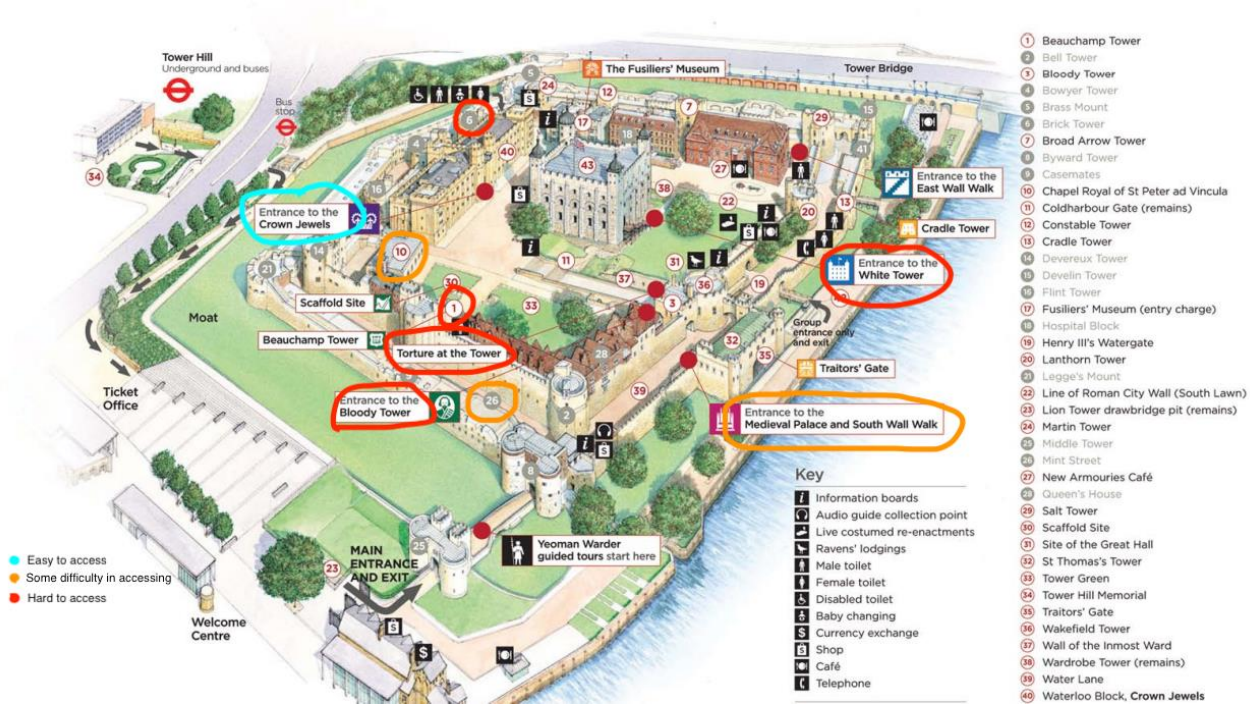

Figure 5: Tower of London attractions map depicting access challenges for mobility impaired visitors (Fitzgerald, 2013)

Currently, HRP is systematically trying to improve accessibility for disabled visitors. A number of wheelchairs are available from the welcome center at the main entrance. The Jewel House is the most accessible place within the Tower of London; it has no steps and the minimum doorway width is 1.02 meters, which is sufficient for wheelchairs. To improve accessibility, there is a platform lift at the end of the moving walkway which allows people to spend more time viewing the Crown Jewels. The Chapel of St. Peter ad Vincula has slightly uneven flooring as well as a few steps located at doorways that make it almost impossible for wheelchairs to access, but it does have plenty of seating and wide aisles which make it easier for mobility impaired people to access. The Tower's Mint has narrow and small exhibition space that is wide enough for regular wheelchairs, but those with wide wheelchairs may need to retrace their route to exit. There is a lift accessible in the White Tower which takes visitors to the basement, where there is a handling collection for visitors to touch. Although the White Tower has a lift to the basement, it is a stone tower with many steps and limited seating making all other floors of the White Tower completely inaccessible to most mobility impaired visitors. All of the other towers have numerous steps, narrow doorways, and confined spaces, and they are not recommended for

mobility impaired visitors (Access Guide, n.d.). The external spaces inside the castle walls are mainly covered with cobblestones, although there are some paved areas in front of the Crown Jewels building (Accessibility, n.d.).

The Tower of London welcomes people with all different types of disabilities. There are volunteers, trained staff, and faculty around to guide disabled visitors. Disabled individuals with service dogs who have designated jackets are welcome inside the Tower, but their owner must have an "Assistance Dogs" identification book. For D/deaf and disabled visitors, induction loops (a sound system that produces an electromagnetic signal received directly by hearing aids) are available throughout the Tower. A British Sign Language tour is also available once a month which follows the standard guided tour to all attractions at the Tower (Accessibility, n.d.). The Tower's BSL interpreters can be identified by a grey badge with the BSL symbol and a bright blue high visibility vest with "BSL interpreter" on the back. Figure 6 shows an image of a BSL interpreter. For blind or partially sighted visitors, HRP offers descriptive tours of the Jewel House and the White Tower. There are also free audio guides and magnifying sheets available to assist these tours. In the basement of the White Tower, the Salt Tower, and the East Wing, handling points are available where blind visitors can physically interact with the structure of the Tower and the other exhibitions. Disabled visitors also receive a concession rate admission ticket that includes bringing an adult assistant free of charge (Accessibility, n.d.). All offered accommodations can be found on the HRP website. Overall, the majority of the Tower of London is not fully accessible for disabled visitors; therefore, HRP is striving to improve access

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Figure 6: A BSL interpreter as shown on the HRP website (Historic Royal Palaces, n.d.)

2.4 HRP mission statement and policies

The mission statement of Historic Royal Palaces is "to help everyone explore the story of how monarchs and people have shaped society, in some of the greatest palaces ever built" (About Us, n.d.). "Everyone" is used advisedly to mean all individuals, including the D/deaf, vision-impaired, and disabled. HRP's goal is to be as inclusive as possible so that everyone, no matter their abilities, is able to experience the Tower of London fully. Historic Royal Palaces has many policies in place to uphold their mission statement, including:

- Equality and Diversity Policy
- Safeguarding Policy
- Collections and Conservation Policy

The Equality and Diversity Policy promotes equality and aims to minimize discrimination against individuals interacting with HRP. HRP's Safeguarding Policy stipulates that a "framework [is followed] for operating a competent safeguarding system and strengthen[ing] safeguarding practice[s]," to ensure that everyone who attends HRP's palaces has an enjoyable and safe experience. Another vital policy is the Collections and Conservation Policy. Since HRP has a Royal Charter, this policy requires HRP to conserve all of their buildings, collections, and interiors to ensure that all of the original aspects of the monument are intact (Policies, n.d.). Keeping all of these aspects intact ensures that HRP can uphold their mission statement.

2.5 Current technologies other museums are using to enhance accessibility

Many museums already have digital technologies in place to improve accessibility for disabled visitors. Table 1 shows a summary table of a selection of current assistive technologies. Appendix B shows a more detailed description of these technologies. The Louvre in France has a downloadable audiovisual guide of the museum that people can view before visiting. The program uses a Nintendo 3DS handheld game console that allows users to take a virtual walkthrough of the Louvre museum and examine the exhibits close up (Bernardo, 2016). This type of virtual walkthrough is useful for people with impaired mobility because they may have trouble accessing exhibits in person. Recently, the British Museum partnered with Samsung to use Samsung Gear VR (virtual reality) to improve mobility impaired visitors' experiences. They are currently using the Samsung Gear VR headset to offer 3D recreations of exhibits (Bernardo,

2016). An image of this headset can be seen in Figure 7 below (Samsung Looks Into Wireless VR Headset, 2016). Many museums have chosen to implement digital technologies to increase accessibility because technology can virtually bring visitors closer to exhibits and provide additional information about each exhibit. In addition to virtual walkthroughs, "telepresence" robots are also being used to help increase accessibility for those who are mobility impaired. These robots allow users to explore museums remotely that they are not able to access physically. The telepresence robots are controlled in real time by users and stream live video of exhibits (Bernardo, 2016). For its visually impaired visitors, The Belvedere[3] is implementing 3D printing to recreate parts of exhibits that visitors can interact with (AMBAVis, 2015). This enables the visually impaired visitors to have a "touch copy" of the exhibit to extend their experience. The Roald Dahl Museum is using mobile applications to increase accessibility for the D/deaf and hard of hearing. Specifically, this museum is using the app Signly to create audio guide explanations of each of the exhibits, as well as sign language guides that these visitors can use directly on their mobile smartphones (Bernardo, 2016).

Figure 7: Samsung Gear VR headset used at the British Museum (Samsung Looks Into Wireless VR Headset, 2016).

[3] The Belvedere comprises two Austrian palaces. It is a museum and is recognized as a UNESCO world heritage site (Museum & Palace, n.d.).

Techonology	Audience	Company	Current Users	Limitations	Operating and Installation Cost	Year Developed
3D Virtual Walkthrough	Mobile Impaired	Ninetendo	The Lourve	Battery life, inaccuracy	130 USD per device	2011
3D Printed Models	Visually Impaired	AMBAVis	The Belvedere and The British Museum	Resolution	1000-10000 USD for the printer	1980
QR code BSL interpreter	Hearing Impaired	Signly	Roald Dahl Museum and Network Rail		Not Available	2015
Telepresence Robot	Mobility Impaired	Beam	The de Yung Museum and Seattle Art Museum	Terrain	5000-15000 USD	2015

Table 1: Overview of current technologies

2.6 Emerging and potential assistive technologies

The use of digital technologies in museums and historical sites is currently a developing concept. These technologies typically focus on augmenting the experience of the museum for fully able guests rather than enhancing the experience of the disabled. One example of a developing technology that has the potential to increase accessibility for visitors is 3D printing. Unlike many museums and historical sites, the Tower of London allows visitors to touch and physically interact with the castle walls and floors, which are part of the visitor journey, but many exhibits, such as the Crown Jewels, are inaccessible to the public via touch. 3D scanning and printing would allow for the creation of tactile models for the use of visitors with impaired vision or blindness. For the vision impaired, any additional level of engagement is highly beneficial and the ability to pick up and interact with replicas of historic artifacts can help to create a much more immersive experience than a descriptive tour can (AMBAVis, 2015).

One area that has not been a primary focus in the efforts to increase accessibility with technology is the issue of visitors with limited mobility. Many of the challenges the Tower of London is facing in regard to accessibility have to do with HRP's inability to modify the physical structure of the Tower to allow visitors with impaired mobility to visit the battlements, chapel, and many of the towers. Virtual Reality (VR) is a quickly developing technology that has the potential to completely change the way this issue is approached. Virtual reality headsets like the Oculus Rift or HTC Vive can be paired with 360-degree cameras that have the ability to capture immersive videos and photographs and allow users to feel like they are actually at the location they are seeing (Shu, 2017). The British Museum has partnered with Oculus to create an immersive tour that potential visitors can experience from home ("New Virtual Reality tour of the Museum with Oculus – The British Museum Blog," n.d.). Virtual Reality headsets on site could allow mobility impaired visitors to visit the more accessible areas of the Tower and then experience a VR tour that would allow them to move around areas that they previously could not. VR, as a technology, still presents many issues for users with disabilities. These issues

include its reliance on motion controls and the requirement that users sit in certain positions in order to view exhibits properly (Ryan, n.d.; "Daydream Labs," 2017; "WalkinVR," 2017).

The American Museum of Natural History in New York City has been placing an emphasis on digital technologies and uses augmented reality to help bring the exhibits to life in a way that could not be done before. As visitors explore the museum, Bluetooth beacons determine their location and present information relevant to the exhibits they are viewing. The application then allows them to delve into the content in a more interactive way on their own personal devices (Erlick, 2017). While this technology would not be helpful in solving accessibility issues in its current state, integration of a service like Signly has the potential to assist disabled individuals. Because most of the experience takes place on the user's own phone, the only physical modification to the museum would be the addition of small Bluetooth beacons. The development of such an application could also serve to augment the experience for visitors without disabilities. This would make visits for groups simpler by allowing all visitors, with and without disabilities, to take the same tour rather than being split up due to the content being presented in the most comfortable format for each visitor.

Another digital technology that is not presently being used for accessibility but could have the potential to be is QR codes. QR codes are a type of barcode that can be scanned by a smartphone and load a webpage, video, or other form of content. QR codes are currently being used in a variety of different settings that range from retailers, to art institutions, to government organizations. The Museum of Modern Art is using QR codes in the "Talk to Me" exhibit and marks the first time QR codes have been used in a museum on every object in an exhibit (Rosenbloom, 2011). Although QR codes have not been used in museums as an assistive technology, their addition to museums exhibits could be beneficial. If HRP placed a QR code on an exhibit, a visitor could scan the code which would display a video, larger text, or an audio recording of the exhibit.

Similar to Bluetooth beacons, RightHear is a system which allows for blind and visually impaired people to acquire a better sense of orientation. By using RightHear beacons in a specific location, users can find out what is around them by simply pointing their phone in any given direction. The system will alert the user whenever they enter or exit an accessible area. The RightHear solution has three main components: a smartphone app which is free for users and is integrated with TalkBack and VoiceOver, small wireless sensors, and a Content Management

Platform, which allows the venue owners to edit and manage the information in real time (RightHear - An accessibility solution for people who are blind or visually impaired, n.d.). Users benefit from RightHear by gaining independence when completing daily activities such as shopping or visiting a museum. Currently, the RightHear system has made about 200 venues accessible but the system requires a large user base for it to work and many visually impaired people do not use smartphones (Blum, B., Leichman, A. K., Amir, R. S., F., & Halfin, 2017).

A Dynamic Shape Display, called inFORM, is currently under development at Massachusetts Institute of Technology. It can render 3D content physically, so users are able to interact with digital information in the physical world. This technology is more efficient, economic, and flexible than 3D printing. Presently, scientists are focusing on 3D rendered content as well as user interface elements through shape output and potential interaction techniques. Although inFORM is only able to make limited shapes and access basic information, it has potential to help individuals with vision impairments explore various exhibits (Leithinger, Follmer, & Ishii, 2013). Figure 8 shows an image of inFORM in action. Table 2 shows the summary table of emerging technologies. Appendix C presents a more detailed description of these technologies.

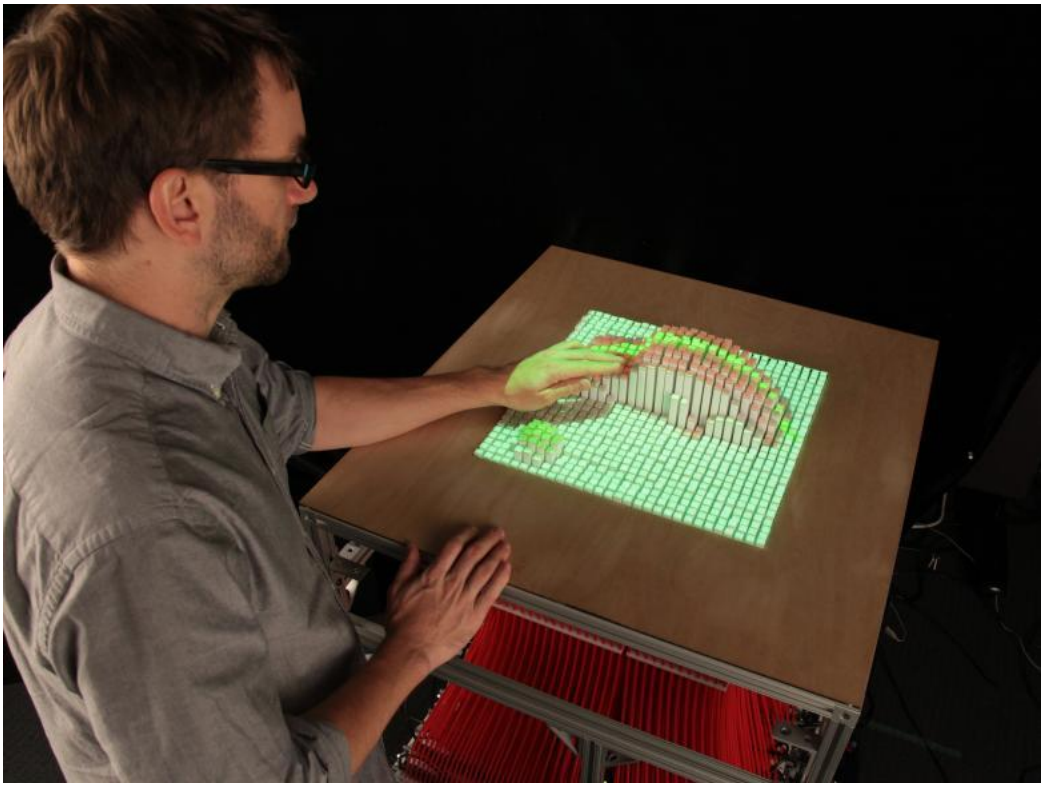

Figure 8: inFORM creates 3D models and can be manipulated in real time (Leithinger, Follmer, & Ishii, 2013).

Technology	Audience	Company	Current users	Limitations	Operating and installation cost	Year developed
Virtual Reality	Mobility Impaired	Samsung	The British Museum	Only one location available per exhibit	In development	
VR Tour	Mobility Impaired		Smithsonian American Art Museum	Dexterity Requirements	In development	
Explorer App	Hearing Impaired	American Museum of Natural History	American Museum of Natural History	Bluetooth beacon battery life	In development	2010
QR Codes	Mobility Impaired	Denso Wave	The Museum of Modern Art	Specific app is required, visually dissatisfying	In development	1994
inFORM	Vision Impaired	MIT	In development	Low resolution large space requirements	In development	2013

Table 2: Overview of emerging technologies

2.7 How assistive technology could help the Tower of London

The previously mentioned digital technologies could help the Tower of London improve accessibility for D/deaf and disabled visitors. For example, the use of virtual reality can allow mobility impaired individuals to bypass stairs while still being able to see the exhibits. However, more than just the technology must be taken into account when considering what will work best for the Tower. Some aspects of these technologies we will consider before making recommendations are the potential impacts they could have on other visitors and the viability of implementation of these technologies at the Tower of London while following the UNESCO guidelines. One challenge that the entire museum sector faces is that certain technologies are disliked by many disabled people because they may be difficult to learn to use. We will take these opinions into account when developing our final recommendation. There are many options for assistive digital technologies; however, only a few will be best suited for the specific needs of the Tower of London.

Through our research we have found many examples of current and emerging assistive technologies. Virtual reality can recreate exhibits for mobility impaired individuals. Descriptive audio guides and directions could be used not only to assist visually impaired individuals, but also assist in navigation of the Tower of London. Additionally, a technology such as a real time speech to sign language translator could be used to assist D/deaf individuals. Through our project we will assess the viability of implementation and recommend specific technologies that can improve access at the Tower of London for disabled visitors.

3. Methodology

The goal of our project was to evaluate how digital technologies can help Historic Royal Palaces (HRP) increase accessibility for D/deaf and disabled visitors at the Tower of. In order to achieve this goal, we identified five objectives:

1. Perform market research to assess digital technologies used to broaden access in the museum and heritage sectors and assess emerging technologies that could be applicable in the future.
2. Assess the current state of accessibility at the Tower of London for D/deaf and disabled visitors.
3. Assess stakeholder opinions in D/deaf and disabled communities regarding the use of technology to promote greater accessibility.
4. Evaluate the viability of implementation of current and potential technologies to promote greater access at the Tower of London.
5. Recommend how HRP might improve accessibility at the Tower of London using digital technologies.

We used a mixed methods approach to fulfill these objectives, including archival research, site visits, interviews, and surveys. Figure 9 illustrates the relationship between our major goal and associated tasks and objectives. Figure 10 presents a preliminary schedule for the completion of these tasks.

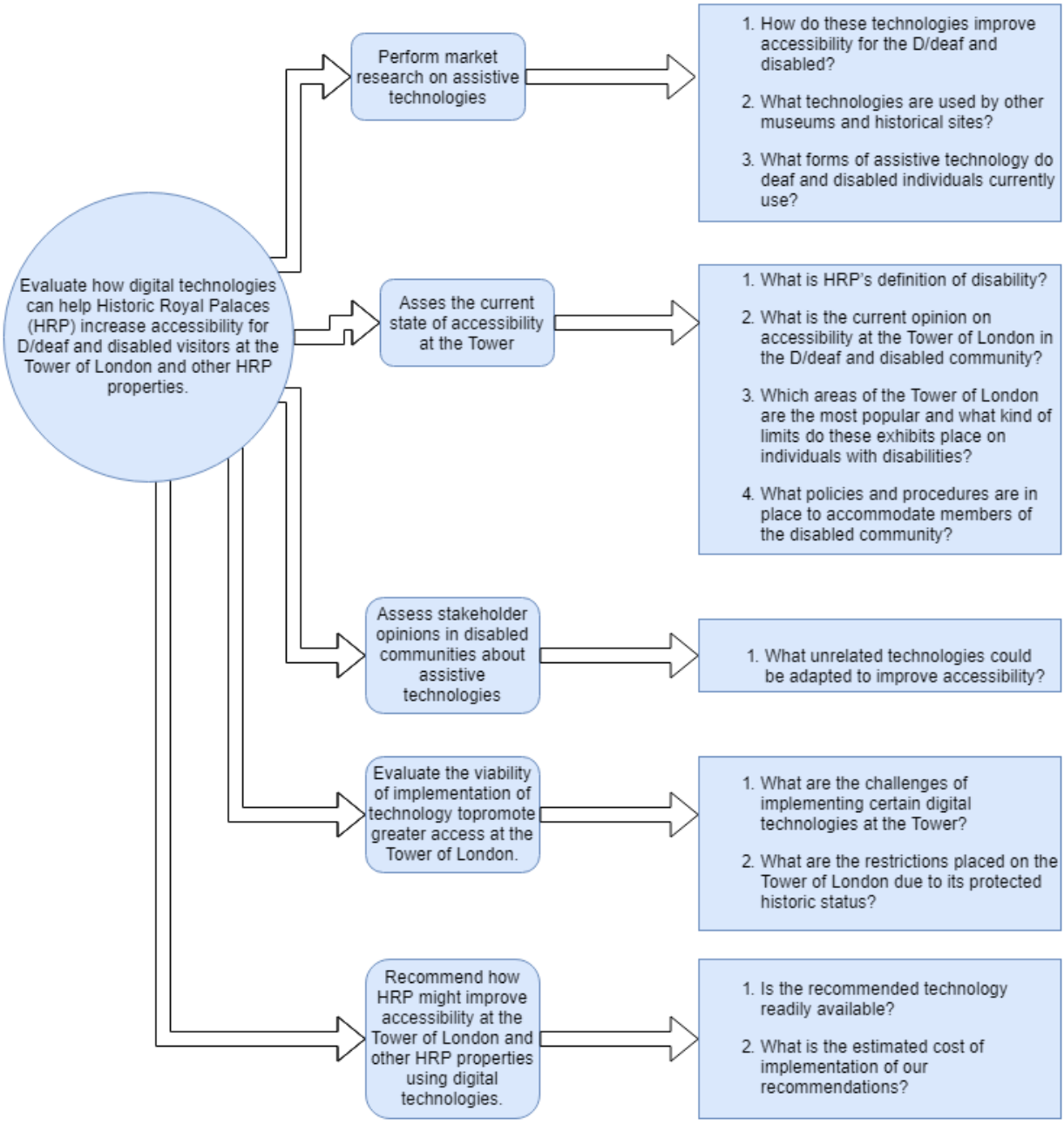

Figure 9: Goals and objectives

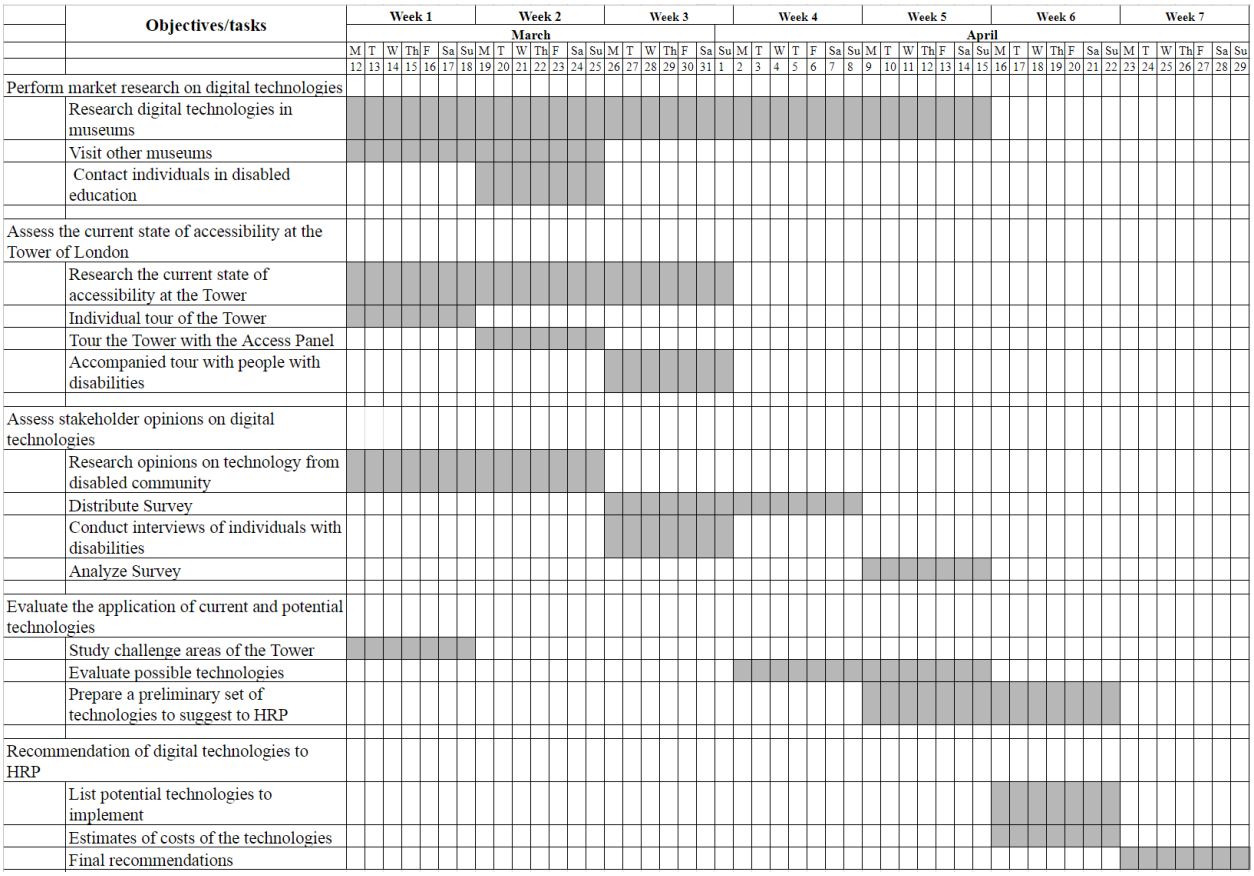

Figure 10: Timeline for tasks to be completed in London

3.1 Objective 1: Perform Market Research on Digital Technologies in Museums

Our first objective was to perform market research to assess the digital technologies used to broaden access in the museum and heritage sectors and assess emerging technologies that could be applicable in the future. As we researched assistive technologies, there were a few questions we focused on such as, what are the best technologies being used presently in museums and heritage sites to enhance access? As well as what digital technologies are emerging that might be used to enhance access, but have not yet been applied to those purposes? We focused on answering these questions as we conducted our research in Worcester, Massachusetts and in London. To supplement our research, we conducted a survey and on-site interviews of disabled individuals to gain a better insight of their preferences. While in Worcester, we researched technologies via the internet to see which assistive technologies are most common. In addition to searching for articles on the internet detailing which technologies other museums use, we went to the Worcester Art Museum to assess what accessibility technologies they have

implemented. While in London we conducted in person, semi-structured interviews of individuals at various museums that have implemented assistive technologies to learn about why they chose the options they did. The sites we selected to visit were the British Museum, the Roald Dahl Museum, the Graeae Theater, and Hampton Court Palace. We chose these institutions because in our research we found various reports stating that the Roald Dahl Museum and the British Museum are some of the most accessible museums in London. Appendices B and C describe some examples of the technologies that the British Museum and the Roald Dahl Museums use. We selected Graeae Theater and Hampton Court Palace to visit based on the recommendation of our sponsors. Appendix D shows the questions we asked our contacts at these organizations. We developed these questions based on our background research and conversations with our sponsors. We focused on how technology enhances the experience for disabled individuals. This aspect of the researched technologies influenced our recommendations because for each area of the Tower of London, different assistive technologies are required. We also considered what problems each technology presents and how these problems would affect visitors at the Tower of London.

3.2 Objective 2: Assess Current State of Accessibility at the Tower

Our second objective was to assess the current state of accessibility at the Tower of London for D/deaf and disabled visitors. In assessing the current state of accessibility at the Tower, we found out what policies and procedures are in place to accommodate disabled visitors. Which areas of the Tower of London are the most popular and what kind of limits do these exhibitions place on disabled individuals? What assistive technologies are in use presently? To answer these research questions, we conducted a review of the publicly available literature on access policies, practices, and the current state of accessibility at the Tower using the official Tower of London website as well as HRP's website. We expanded this background research by reviewing additional internal documents when we arrived in London. We conducted research to find specific areas and exhibitions that are currently not accessible but could be with digital technologies.

Once we arrived in London, we took multiple tours of the Tower to assess its state of accessibility. First, we explored the Tower as a group to formulate our own opinions on the state of accessibility before others influenced us. To assess the state of accessibility at the Tower, we

looked for places that have dim lighting, small text, distant exhibits, narrow passageways, uneven flooring, steps and stairs, and poor room acoustics. These factors may prevent an individual with disabilities from fully experiencing the complete "visitor journey." After exploring the Tower individually, we took various accompanied tours with disabled people. Our sponsors made the logistical arrangements for these tours. There were six accompanied tours in total: two visits with mobility impaired visitors, two with vision impaired visitors, one with a D/deaf individual, and one with a hard of hearing individual. This diverse set of accompanied tours allowed us to see certain areas of the Tower that are not accessible for people with a variety of disabilities. In addition to observing the individuals that we toured with, we conducted an in person, conversational interview with these people about their experience. We conducted these interviews at the Tower vaults. We asked all the interview questions at a post-tour interview with these disabled individuals to identify challenges that they experienced during their tour. Appendix E shows a list of the questions we asked disabled individuals for the supplemental interview. Subject information obtained in these interviews will remain confidential and no identifying information will be reported without consent of the subject. A major concern that we were aware of when completing this objective was which areas of the Tower of London are the most popular and what kind of limitations these exhibitions placed on disabled individuals.

We also met with the Head of Operations & Security, the Tower Operations Manager, the Visitor Services Manager, and the Visitor Services Coordinator. During this meeting, we discussed the Tower's recent Access Review as well as some anecdotal feedback on accessibility at the Tower. This feedback included comments that visitor services has received from disabled visitors as well as general themes in this feedback.

3.3 Objective 3: Assess Stakeholder Opinions Regarding Accessible Digital Technologies

Our third objective was to assess stakeholder opinions in the D/deaf and disabled communities regarding the use of technology to promote greater accessibility. We wished to know what assistive technologies members of the disabled community have found most useful in museum settings as well as in their daily lives. In particular, we were interested in any technologies used by the disabled community which were not necessarily designed to improve accessibility but could be used to assist disabled individuals during their visit to the Tower.

Building on our research conducted in Worcester, we conducted a structured survey of members of D/deaf and disabled communities. We worked closely with HRP to ensure that the survey was sensitive to disabled people. We created the survey in Qualtrics and our sponsor distributed the link to the survey to various groups of disabled people. HRP explored the best way to make the survey accessible to all individuals; this resulted in a text and a British Sign Language version of each question. The data collected from the survey is stored on confidential HRP servers which require authentication to be accessed. Appendix F shows the survey. In the survey we asked questions about which types of assistive technologies disabled people use on a daily basis as well as types of technologies that might help improve accessibility in their daily lives. We also asked if there are any digital technologies that disabled people have used at other museums in the past year that they think helped improve accessibility during their visits. This gave us a better sense of what technologies work well and which ones present challenges to the museums or users. In order to help the Tower of London specifically, we split the path of the survey depending on whether people have visited the Tower or not. Asking people if they have been to the Tower before helped us understand why they choose not to visit or if they have visited, what challenges they faced.

To supplement the survey we conducted in person, semi-structured interviews of individuals that work at other museums or heritage sites. We identified individuals to interview through HRP and contacts of our sponsor. The interviews took approximately 30 minutes but no more than 45 minutes. We conducted these interviews at the museum where the subjects work so we could tour the museum and experience the assistive technologies as well. Appendix D shows a list of these interview questions. Through these interviews we gained a better understanding of the digital technologies preferred by disabled visitors based on feedback that other museums have received. One of the questions we considered as we conducted our research was, what technologies are used by other museums which are not necessarily intended to be assistive? Our sponsor requested we keep an open mind as we explore digital technologies and look for technologies which were not designed to be assistive but have the potential to help disabled individuals. When we interviewed the museum representatives we asked them about feedback they received on the digital technologies they offer. We kept this on the forefront of our minds as we conducted our research; we wanted to ensure that the technology we selected for our recommendations are well liked by the community.

3.4 Objective 4: Evaluate the Viability of Implementation of Current and Potential Technologies to Promote Greater Access at the Tower

The fourth objective for this project was to evaluate the viability of implementation of current and potential technologies to promote greater access at the Tower of London. We thoroughly researched different technologies that could improve accessibility. However, because of its historical significance and protected status, the Tower of London has some unique restrictions on the physical changes can be made and therefore, the types of technologies that can be implemented. By studying these challenges and how they related to the technology that we found in our market research, we ruled out technologies that would be impractical for use at the Tower. Challenges such as limited space and the restrictions on physical modifications prevented many of the more traditional technological approaches to accessibility from being implemented. To accomplish this objective, we toured the Tower after having prepared a preliminary set of technologies that could be useful. As we toured the Tower, we assessed the potential challenges of implementing various technologies in different areas of the Tower. Information about the spaces at the Tower is available through HRP and online but without experiencing the spaces in person, it was difficult to pass judgment on a potential solution. Additionally, we assessed whether or not an evaluated technology offered something new to the Tower in terms of accessibility or if the considered technology is redundant. Once we understood the state of accessibility at the Tower by working through our first objective, we were better equipped to complete this fourth objective.

3.5 Objective 5: Recommend How HRP Can Improve Accessibility with Digital Technologies

The final objective was to recommend how HRP might improve accessibility at the Tower of London using digital technology. After completing our other objectives, we gained a better understanding of many different digital technologies that could have applications in increasing accessibility at the Tower of London. To help HRP, we created a summary that outlines the technologies that we are recommending, the reasoning behind the recommendation, and an explanation of the challenges and costs associated with the implementation of the suggested technology. We then researched the proposed technologies further to provide HRP

with a detailed description of the process of implementing the technology, as well as any potential concerns in implementing it. One major challenge in completing this objective was the difficulty in finding estimates of the costs associated with implementing each suggestion. For products like virtual reality headsets or Bluetooth beacons, estimating the cost of implementation was straightforward; but when we considered services such as 3D scanning and virtual reality mapping, price estimating is not available. While our report may not be the only source of information consulted if HRP decides to implement one or more of the technologies we found, we hope to help HRP to gain an understanding of each technology and simplify their decision-making process.

3.6 Conclusion

To complete our project goal, we assessed the current state of accessibility at the Tower of London and researched possible digital technologies to assist disabled visitors. Based on our findings, we provided potential solutions as to how digital technologies can help HRP increase accessibility for D/deaf and disabled visitors at the Tower of London.

4. Findings

Through our research we formed opinions as to what access challenges at the Tower could be solved using digital technologies. Additionally, we gained insight as to what kinds of assistive technologies disabled people prefer. We used feedback from the Tower's Access Review, other museums, accompanied tours, and our survey to form our recommendations.

4.1 Our observations

Upon arriving at the Tower, we dedicated several days to familiarizing ourselves with the Tower through various walkthroughs and tours. During this exploration, we looked for specific locations at the Tower that we thought might present access challenges.

One of the largest barriers for mobility impaired individuals at the Tower is the cobblestones that make up most of the walkways around the inner and outer wards of the Tower. These cobbles vary in size and spacing and present a number of challenges for disabled visitors. Visitors using an electric wheelchair over these cobbles would have a hard time and it would be even more difficult for a visitor to operate a manual wheelchair on the cobbles by themselves. Additionally, for blind visitors, the cobbles change level and have sunken grates that would be easy to trip over and may not be detected by a probing cane. Navigating these cobbles is a necessity for navigating the Tower and there are few routes between buildings that do not contain cobbles.

The White Tower is unique in that it is one of the most accessible areas at the Tower for blind and D/deaf visitors but is almost completely inaccessible to visitors with mobility impairments. The basement contains a gift shop and viewing gallery that is accessible via lift; however, the viewing gallery is somewhat limited in the scope of displayed items. It contains almost exclusively cannons and munitions and has very little armor compared to upstairs. The upper floors are impossible to access if a visitor is in a wheelchair or cannot use stairs. An additional challenge with the inaccessibility of the upper floors is that many of the tactile exhibitions available at the Tower of London are on the upper floors of the White Tower and if a visitor is blind and mobility impaired they cannot access these exhibitions.

The Jewel House is advertised in the access guide and on the website as the most accessible area at the Tower but there are still some challenges that we noticed during our walkthroughs. Throughout the exhibition, the level of lighting is very low. Text on the walls is

difficult to read even for visitors with full vision due to low contrast. Additionally, a soundtrack of muffled voices and music plays in the background and would make conversation and staff instructions difficult to understand for a hard of hearing visitor. When the exhibition is crowded, it is difficult to navigate through the building in the low lighting. We observed that the low contrast of text on the walls of different towers made it very hard to read compared to the high contrast of text on information panels and text describing each piece of regalia in the Jewel House.

When touring the Tower of London, we noticed many of the same accessibility challenges between each tower and the battlements. The frequent level changes as you move along the battlements from one tower to the next are difficult to navigate for non-disabled visitors and almost impossible for mobility impaired or blind visitors. Many of the inscriptions on the walls can be difficult or impossible to distinguish for visually impaired visitors. The text describing the inscriptions is grey or black on a clear background so depending on the color of the stone behind it, the text can be very difficult to read. Additionally, in many of the towers around the battlements, poor room acoustics make conversation difficult and the audio guide hard to follow unless the visitor is using headphones.

4.2 Access Review

We analyzed the Tower's Access Review that was conducted by Goss Consultancy. Goss Consultancy was hired by HRP to conduct an Access Review of the Tower of London in June of 2017. In the Access Review Goss Consultancy highlighted every instance of accessibility challenges they found and categorized them based on their location. One recommendation that Goss Consultancy made in particular was that the Tower could benefit from assistive digital technologies.

Through our analysis of the Access Review we selected areas which we felt would benefit from the implementation of digital technologies. We read through every instance of an access challenge and categorized each challenge based on what type of assistive technology we thought could solve each problem. We determined that the access challenges that could most effectively be solved using digital technologies were the lack of BSL, the presence of steps and spiral staircases, and the lack of contrast and lighting. While the Access Review was very useful in helping us determine what access challenges to focus on, the Access Review did not propose

any digital technology solutions. The Goss Consultancy Access Review was quite harsh and painted the Tower in a poor light which prompted HRP to sponsor this project.

4.3 Results from interviews

To gain insight about how digital technology can improve accessibility at the Tower of London, we interviewed employees at other museums and heritage sites, including Graeae Theatre, the British Museum, Hampton Court Palace, and the Roald Dahl Museum. We asked about their general accessibility offerings, the required maintenance on their current assistive technologies, and their future implementation plans of emerging digital technologies.

4.3.1 Graeae Theatre

Graeae Theatre is known for its work with disabled artists and actors as well as its fully accessible office building. For their shows, the theater uses easy read format for the programs, actors who sign throughout the performance, and 3D models of the stage that visitors can touch to familiarize themselves with the set. We met with two people from Graeae Theatre to discuss our project as well as the proper language for our survey. First, they explained the differences between the medical model and the social model of disability. The information about the best practice language under the social model was very different from what we found from our research in the U.S. We thought that the best way to reference a disabled person was using person first language although we learned that under the social model, this is not preferred. In an effort to make our survey more accessible, Graeae recommended that we produce a BSL version of the survey in addition to simplifying questions and asking questions in multiple choice format when possible. Additionally, Graeae worked with us to develop a list of access requirements for people to choose from rather than asking what their impairment is. They also emphasized to us the importance of ensuring full screen reader compatibility for the survey so that blind and visually impaired visitors can access it. Once we completed the draft of our survey, they gave us very helpful feedback on it and referred us to a BSL interpreter, Daryl Jackson, to help film the videos.

At the end of the visit, we toured the Graeae office to observe their accessibility measures. There was different texture on ground surfaces to indicate moving into a new space, color coded doors to indicate the type of space behind the door, lighting that was adjustable and recessed in order to capture echoes, braille, wide automatic doors, and accessible bathrooms. In the rehearsal room, they had soft flooring and railings to meet different accessibility requirements.

4.3.2 The British Museum

The British Museum is well known for its accessibility and its recent partnership with Samsung to use VR in their Digital Discovery Centre. We interviewed Natalia Hudelson and Carlos Austin-Gonzalez who work with the digital visitor guide as well as Elizabeth Porter, the interim Access and Equality Manager, to understand more about the British Museum's accessibility offerings.

The British Museum has been working with organizations like VocalEyes to improve accessibility for disabled individuals. VocalEyes is a charity that helps blind and partially sighted people experience the arts. They also helped the British Museum to develop their descriptive audio tour. In terms of data collection, the British Museum relies on visitor research, incentives for surveys, and focus groups because it is hard to find large access groups for user related research of assistive technologies. Currently, BSL and descriptive audio tours are the only accessibility technologies offered at the British Museum. The old audio guide was on a traditional keypad device which was outdated and hard to update. They decided to upgrade to a smartphone-based system for the BSL tour and the standard audio tour. They have a separate device designed for blind visitors for the descriptive audio tour. Since the update in 2015, there has been a 40% increase in usage of the visitor guide. Battery life and storage space on audio devices are currently the main challenges for the smartphone based visitor guide.

The British Museum has lifts so that mobility impaired individuals can get to upper floors but they may not be able to follow the normal routes, and it can be hard to navigate through crowds and eating areas. Eventually, the British Museum would like to implement an app to help mobility impaired individuals; however, it is hard to decide what kind of technology to use in a museum. Museums are often hesitant to add more technology because there is a perception that it interferes with the connection between the visitors and the displays. After discussing these measures, we toured the British Museum with the audio guide and BSL tour. Both were useful when working but the audio version occasionally began playing foreign language audio at the same time as the English information which made words indistinguishable.

4.3.3 Hampton Court Palace

Hampton Court Palace is one of the more accessible HRP properties. There is a lift located inside the palace and the property itself is somewhat wheelchair friendly. Their BSL tours are usually very popular to the point that it can be difficult for the D/deaf individual to see the tour guide. Due to the popularity and the limited amount of BSL tours, visitors have to pre-book their tour for a specific day.

For current assistive technology, Hampton Court Palace offers traditional audio tour devices. In general, Hampton Court Palace is considered accessible for a site in the heritage sector because of their lift, but they see room for improvement in the marketing of this information. For future assistive technology implementation, Hampton Court Palace would like to add a BSL digital visitor guide. We toured Hampton Court Palace and while they do have some good indication of level changes and access routes, more maps and wayfinding information may be helpful.

4.3.4 The Roald Dahl Museum

The Roald Dahl Museum is using the mobile app, Signly, to increase accessibility for hard of hearing individuals. During our visit, we found Signly very easy to use. Signly uses a modified QR code along with an app to scan the QR code and see the BSL translation of the displayed information. However, you have to hold your phone in front of the code and at the right angle the entire time otherwise the video will disappear and restart. The Signly app has received positive feedback from user testing; however, the Roald Dahl museum only has short

BSL videos attached to each QR code and they wish to have more detailed descriptions of exhibitions on Signly. Around the museum they also have written descriptions of exhibits, text narrations of videos, accessible doors for wheelchairs, hearing loops, and audio description displays.

4.4 Results from accompanied tours

To gain insight into the access challenges faced by a disabled person when visiting the Tower of London, we conducted accompanied tours with six individuals with different types of disabilities. These accompanied tours allowed us to observe the challenges encountered so that we could assess which digital technologies would best fit the Tower's access needs.

4.4.1 Accompanied tour with a full-time wheelchair user

The first accompanied tour that we conducted was with a full-time electric wheelchair user who also had limited dexterity. After touring with visitor 1 we were aware of the access challenges at the Tower for a wheelchair user. These challenges include using a wheelchair to traverse the cobbles, navigating crowded areas and exhibits, navigating tight pathways in exhibits, using the current version of the access guide, and reaching stairs that prevent the visitor from fully experiencing the Tower. Visitor 1 also mentioned that the sign postings for wayfinding around the Tower are useless because it is very unclear where they are leading and they most likely will not be leading the visitor via a step-free route. One of the praises that visitor 1 had was about the Coins and Kings exhibition. The visitor indicated that the heights of the displays were accessible for a wheelchair user although the pathways were narrow and difficult to navigate. In terms of recommendations that could make the Tower more accessible, visitor 1 said that using a mobile application that has a digital map and wayfinding information would be very helpful because the signage around the Tower is hard to read and understand. The visitor also said that a mobile application that showed each part of an exhibit and a description of what they were looking at would be very helpful to see things that are high up and cannot be seen properly from a wheelchair. Appendix G details a full list of all our observations and the visitor's comments during accompanied tour one.

4.4.2 Accompanied tour with a hard of hearing individual

The second accompanied tour was with a hard of hearing person. From this visit we observed the challenges encountered by a hard of hearing person at the Tower, such as watching videos and hearing staff instructions. Poor lighting on displays made reading signs difficult for visitor 2. Additionally, the visitor had a hard time using the map to navigate the Tower. Visitor two abruptly ended their visit after seeing the Crown Jewels and Beauchamp Tower due to the lack of accessibility and the fact that the visit was very frustrating for them. The visitor was angry about the dim lighting in the Crown Jewels because they are self-described as a completely visual person and due to the dim lighting, they could not read all the displays properly. In addition to this, there was an interference with the visitor's hearing aid in the Crown Jewels building and the visitor stated that if their assistive technology cannot work properly, they would rather have nothing. The visitor then proceeded to take out their hearing aids. The visitor was also very passionate about adding subtitles to all videos so that they could understand what was happening. Visitor two said that virtual BSL tours would be very helpful since it may be inconvenient to visit on the one day a month that BSL tours are offered at the Tower. Appendix H shows all the observations and comments made during the accompanied tour with visitor 2.

4.4.3 Accompanied tour with a mobility impaired individual

Accompanied tour three was with an individual with a mobility impairment that caused them to be unable to use steps or stand for long periods of time. This visit highlighted the access challenges faced by someone with a mobility impairment, such as walking on the cobbles, navigating the moving walkway at the Crown Jewels, walking long distances to various exhibitions at the Tower, and being unable to take the Yeoman Warder tour due to the walking speed. Additionally, the visitor noted that a variety of seating was important because they require frequent breaks but if a seat does not come up to at least knee height, they are unable to stand back up. The visitor indicated that they would have been very frustrated if they had paid for a ticket to the Tower since they were only able to access a small fraction of the Tower. Appendix I lists all observations and comments from the accompanied tour with visitor 3.

4.4.4 Accompanied tour with a D/deaf individual

Accompanied tour four was with a D/deaf individual who required an interpreter. Through this visit we learned about the access challenges faced by a D/deaf individual when visiting the Tower of London, such as being unable to do a Yeoman Warder tour, watch the reenactments, or use the audio guide. The dim lighting in the Crown Jewels, lack of BSL, and lack of captions on videos around the Tower posed major challenges for visitor four in being able to communicate and understand what they were looking at. The visitor said that there should be a D/deaf tour using BSL lead by a D/deaf person so that they would be able to directly communicate and not have to go through the trouble of using an interpreter. The visitor also mentioned that the Signly application is very good and helpful with providing a BSL version of all text on displays. Visitor four also said that the person signing the BSL for the Signly application should be a D/deaf person who is passionate and informed about the subject matter so that they will be familiar with the jargon that may be needed when talking about the Tower of London. In addition to Signly, the visitor mentioned that having a personal key fob that activates closed captions when they are near a video would be helpful. Appendix J provides a detailed description of all observations and comments made during the accompanied tour with visitor 4.

4.4.5 Accompanied tour with a legally blind individual

The fifth accompanied tour that we conducted was with a legally blind individual who uses a single lens magnifier and an indicator cane. Through the accompanied tour with visitor five we were made aware of the access challenges faced by a legally blind person such as dim lighting, low contrast on text displays, and distance of text displays from the glass. The visitor had an especially hard time reading certain text displays because when they bent down to get close enough to read it with their magnifier, their body blocked the light and cast a shadow over the text, so it was completely dark and unreadable. Due to the bad contrast on displays, the visitor suggested that the ideal contrast would be a dark wood background with off white text. Figure 11 shows one example of the ideal contrast which was pointed out to us by visitor 5. Visitor five believes that digital technologies could help enhance the experience at museums for disabled people. However, in their everyday life, visitor five prefers human interactions over digital technology because in-person experiences offer the opportunity for clarification if needed.

Appendix K lists all the observations and comments collected from the accompanied tour with visitor 5.

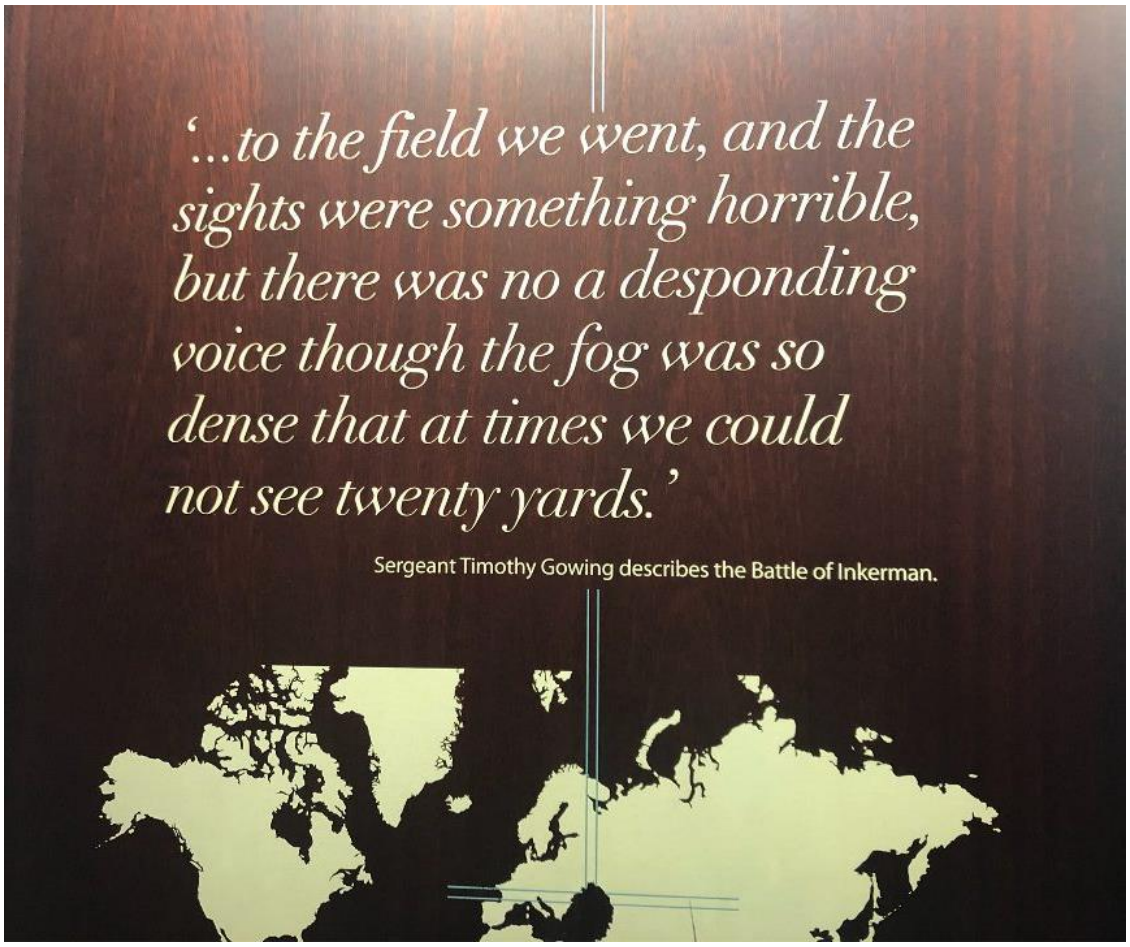

Figure 11: Sample of the best contrast for signs displaying information found in The Fusilier Museum at the Tower of London (High contrast sign, 2018).

4.4.6 Accompanied tour with a blind individual

The last accompanied tour that we conducted was with a blind person. We were able to observe the access challenges faced by someone who is fully blind when visiting the Tower of London, such as viewing exhibits, wayfinding, navigating stairs and level changes, and using the audio guide. The major challenge faced by visitor six was the audio guide. The staff did not teach visitor six how to use the audio guide; we had to show them. In addition, the buttons on the audio guide were worn down and the visitor had a hard time determining which buttons to press. The audio guide also uses pictures to orient the visitor and it did not clearly describe where each

section started. Due to all of these challenges in using the audio guide, visitor six indicated that a more specific audio description would be much more helpful. Although the visitor does not visit museums often because they think museums are generally inaccessible, they think that digital technology could help increase accessibility and provide independence at museums if implemented correctly. The visitor also suggested that a variety of technologies should be available at museums so that visitors can choose to use one with which they are familiar, Appendix L shows visitor 6's comments and observations from their accompanied tour.

4.5 Results from survey

Our survey contained 21 questions and was distributed in both BSL and text versions. Within three weeks, we received 153 responses, including partial responses. The amount of responses to each question varies because many questions were non-mandatory; therefore, some respondents chose to skip questions. Due to the small number of responses, we could not use our survey to draw conclusions about any population larger than the survey respondents. Appendix F shows a full list of the survey questions we distributed.

4.5.1 Perceived access challenges at the Tower

To find out about the perceived access challenges at the Tower, we asked if there is a particular access barrier that has prevented them from visiting the Tower. In response to this question, five out of fourteen respondents said that they assume wheelchair access is limited due to the age of the building and the number of cobbles. Also, one out of these five worried that it would be hard work for the person pushing the wheelchair. Other respondents said that there are not enough BSL interpreters which deters them from visiting.

To gain a deeper understanding of the potential visitors' hesitations for visiting the Tower we asked if there is anything they would like to tell us or think we should know. Three out of six respondents said that there needs to be better wheelchair access because either they or a family member cannot visit due to bumpy terrain and lack of lifts. One respondent said text on all displays should be a larger font size. Another respondent said that there needs to be more D/deaf awareness at the Tower and there needs to be someone available at all times if D/deaf individuals have a question. One respondent said there needs to be digital displays available to give more information about each exhibition if needed, while another respondent said staff needs better

training about accessibility. One respondent said D/deaf people do not know when videos have sound effects and since the staff does not know how to sign they may have an incomplete experience. Based on the survey responses, we found that it is hard for mobility impaired individuals to visit the Tower since there is not much for them to access and therefore they cannot fully enjoy their visit. Hard of hearing respondents to the survey found that there are not enough BSL tours at the Tower. Based on our research, the Tower only offers BSL tours once a month and at a specific time. During the BSL tours, the majority of the staff is unable to communicate with D/deaf visitors. Mobility impaired individuals stated that there is not a clear step-free route and the signage indicating the step-free route is unclear.

Along with the perceived challenges at the Tower, we asked survey respondents what access requirements they have. From this question, we found that places to sit throughout the venue and wheelchair access were the most common responses. Although the Tower of London is perceived to be inaccessible, multiple respondents said Hampton Court Palace is highly accessible due to their level access and mobility scooters.

4.5.2 Preferred assistive technologies

In the survey, we asked if respondents were familiar with any technologies that would help improve access in their daily life. This was a free response question that allowed visitors to give examples of any technology they were aware of. To increase access, two out of six BSL respondents said they would like an iPhone/iPad BSL interpreter app and four out of 46 respondents said VR would help. Two out of 46 respondents said tactile maps would be beneficial and six out of 46 respondents said mobile apps would help in increasing accessibility. We then asked if respondents knew of any technologies that that would have improved their experience at the Tower. Four out of 32 respondents want a technology that provides a BSL interpreter directly on their phone. Three out of 32 respondents would like to have a VR tour and 2 out of 32 would like online maps or a clearer map indication. Four out of 32 respondents need closed captions and two out of 32 said large text is necessary to increase accessibility at the Tower.

To avoid suggesting technologies that would not be well received, we asked respondents if there were any particular technologies that they actively avoid. From the responses, most of the BSL users avoid any screen without subtitles. Six out of 49 respondents said they try to avoid

audio tours because they could be difficult to use and annoying to carry around. These results from our survey helped us to form recommendations that would abide by the preferences of disabled visitors.

4.5.3 Accessibility of online information

Sixty nine out of eighty respondents indicated that they look for accessibility information online before a visit to a cultural or heritage site, indicating that the quality and ease of access of this information is very important. We also asked if respondents have encountered any challenges when viewing the accessibility information online for the Tower of London. Responses indicated that some information is unclear about access for D/deaf people. Furthermore, we asked if there is any accessibility information (e.g. information to help D/deaf and disabled visitors plan their visit) about the Tower of London they would like to be made available on the website. Responses indicated the following would be useful to provide on the website: a large print download of the access guide, disabled discount ticket information, and a list of quiet spaces at the Tower. Many respondents would like to be able to find information about the number of steps around the Tower, the possibility of queue jumps, and the wheelchair access route on the website. Respondents additionally indicated that accessible toilets, quiet spaces, and distances between locations should be shown clearly on maps.

5. Recommendations

Through our research we found many digital technologies that could improve access at the Tower of London. We also have a number of suggestions that do not pertain to digital technologies that we believe would greatly improve the experience for disabled visitors at the Tower. These recommendations include elements of the entire visitor journey, from pre-visit research of accessibility information to exhibitions at the Tower.

5.1 Digital technology recommendations

Access at the Tower of London can be improved using digital technologies. Appendices B and C show the technologies we found which have the potential to improve access. However, not all of these technologies are suitable for implementation at the Tower. From the results of our research we have selected the technologies which best fit the needs of the Tower. These technologies include 3D scanned and printed models of objects on display, Signly, and VR tours. We recommend that HRP strongly consider these technologies for implementation at the Tower in the near future. There are also technologies that are not yet viable for implementation at the Tower that we recommend HRP monitor, such as inFORM, Righthear, and telepresence robots. While these technologies are not currently available they could greatly improve accessibility once they are refined and available for purchase.

5.1.1 3D scanned and printed models

3D printed models of objects on display at the Tower of London would greatly improve access for visitors with a visual impairment. The Tower already has 3D models, such as the brass casings of the Crown Jewels; however, 3D models of objects on display in the White Tower could help a visually impaired visitor more fully experience an exhibition. Additionally, 3D printed models of areas rather than objects could help visually impaired visitors gain a better understanding of their surroundings. Visitor four pointed out that a 3D map with braille labels could help blind visitors navigate the Tower. We recommend that 3D models be made of the Tower and placed near the entrance to serve as a map and an introduction to the layout of the Tower for blind visitors. Additionally, we recommend that 3D models of the rooms in the towers around the battlements be made. These 3D models will help blind and visually impaired visitors to experience the Tower of London more fully.

The price of the 3D scanning and printing is unclear due to the size of the rooms, number of models, size of the models, and desired resolution. In addition to the 3D models, braille should be present either on or near the model to describe what the model is and why it is important. Braille should also be added to the 3D models currently on display at Tower.

5.1.2 Signly

Audio guides are an effective way to present information to visitors who are not able to read descriptive signs or plaques. However, D/deaf individuals that require BSL or captioning may not be able to use them. Signly is a company that has created an app which uses custom QR codes to display BSL translations of displayed information. Figure 12 shows an example of one of the custom QR codes at the Roald Dahl museum. The user can download the Signly app on their smartphone and as they navigate the museum they can use the app to scan each QR code. Once the code is scanned a BSL video will appear and continue to play as long as the phone is pointed toward the QR code. While the current form of Signly suits the Roald Dahl museum well, we suggest that the Tower implement Signly with a few modifications. We recommend that HRP work with Signly to allow people to move away from the QR code without stopping the video. This would reduce the crowds around popular exhibitions, such as the Crown Jewels. Additionally, Signly should be modified to play an audio description, show a BSL translation, or display a text description of the exhibition based on user preference. Accompanied tour visitor two stated that in the past they have had problems with the reliability of QR code scanners and is hesitant to try them. To improve the reliability of Signly we recommend that Signly add a feature that allows users to input a number manually to start the description as they would with a traditional audio guide. We also recommend that HRP download the Signly app to their Digital Visitor Guides because accompanied tour visitors one, two, and five indicated that their phones would not be able to either download or run Signly. The cost of implementation of Signly would have site specific costs and is therefore unclear. However, while it will cost more initially, we recommend that HRP order plastic QR codes that adhere to the displays rather than stickers because Steve Gardam from the Roald Dahl museum stated that they have has issues with sticker versions of the QR codes peeling off. Through the implementation of Signly accessibility can be improved for all visitors at the Tower of London.

Figure 12: Sample of a custom QR code that Signly uses at the Roald Dahl Museum (Signly, 2018).

5.1.3 Virtual reality tours

There are many areas of the Tower of London which are only accessible by staircases, such as the White Tower, the Chapel of Saint Peter ad Vincula, and the Battlements. These areas are often entirely inaccessible to mobility impaired individuals. VR technology allows individuals to view areas even if they are not physically there. By taking a 360-degree picture of the areas that are not accessible visitors will have the opportunity to experience parts of the Tower which were previously inaccessible. We recommend that VR experiences initially be set up at the White Tower, the Chapel of Saint Peter ad Vincula, and from select views on the Battlements. These areas are exhibitions which accompanied visitors one and three stated they would like to visit most as we toured the Tower. Moving forward we recommend that all areas which are inaccessible to mobility impaired individuals have a VR experience. The HTC Vive headset should be used for all VR experience locations at the Tower because they offer a clear visual display with large, ergonomic controls. Figure 13 shows the HTC Vive headset and

controls. The controls of the HTC Vive will be especially useful for any individuals that have limited dexterity. Each HTC Vive retails at £499 (HTC Vive, n.d.). While there are less expensive options, such as the Google Cardboard which retails for £6, these options do not offer the same video resolution and are often uncomfortable to use (Google Cardboard,Virtual Real Store 3D VR Headset Virtual Reality Glasses Box with Big Clear 3D Optical Lens and Comfortable Head Strap Nose Pad for All 3-5.5 Inch Smartphones, n.d.). One further consideration to note about virtual reality is that a computer with sufficient graphics processing power will be required to render the virtual reality environments.

Figure 13: The HTC Vive headset and controllers (HTC, n.d.)

5.1.4 inFORM

While 3D printed models can be implemented currently, HRP should also monitor inFORM. A technology currently being developed at Massachusetts Institute of Technology, inFORM can recreate multiple 3D models from stored data. A grid of adjustable height columns allows inFORM to create dynamic displays of various objects. The biggest advantage that inFORM has over traditional 3D models is adaptability. Once a traditional 3D model is made it can only be used at the display for the object; however, new files can be uploaded to inFORM that can change which model is on display at any time. Display cases with multiple objects inside

could also benefit from inFORM. The visitor could push a button and inFORM could change to recreate the selected object, then once the visitor wishes to see another item on display, a different button could be pushed to recreate an entirely different object. This would prevent multiple 3D models from cluttering the area around a display case. Price and information about the process of implementation is not yet available because inFORM is still in the early stages of development. While inFORM seems like a promising option to improve access at the Tower in the future, HRP must carefully consider the reliability of inFORM and the customer feedback once it is released before deciding if it suits the needs of the Tower of London.

5.1.5 Righthear

Righthear is a Bluetooth beacon system used to help blind or visually impaired individuals navigate and display information when the user is in the proximity of an exhibition. The user can download an app onto their iPhone or Android device which interacts with Bluetooth beacons. These Bluetooth beacons will prompt information to be displayed on the phone without user input. For example, if a user walks into the Bloody Tower, Righthear would automatically display information about events that took place in the Bloody Tower. The user can also use the app to get directions to navigate from one area to another using the Bluetooth beacons. As the user moves from one Bluetooth beacon to the next, directions can change and adapt to ensure the user gets to their destination. We recommend that if HRP decides to implement Righthear in the future that the app be added to the Digital Visitor Guide because accompanied tour visitor four indicated that it would be very convenient if everything was in a single device. If HRP chooses to implement Righthear once it develops further one aspect of Righthear to consider is if the beacons are strong enough to emit over a large area such as one floor of the White Tower but not so strong that it will interfere with the floors above or below. Additionally, the method of powering the Bluetooth beacons should be carefully considered before implementation. If the Bluetooth beacons are battery powered, then a strict schedule must be maintained for changing the batteries. If the batteries are not changed regularly Righthear could cause more problems than solutions because accompanied visitor 2 indicated that if their assistive technology was not working, then they would rather not have the technology at all. While Righthear offers a solution to wayfinding and displaying information for blind and visually impaired visitors, the reliability must be considered before implementation.

5.1.6 Telepresence robots

The Tower of London has many physical structures, such as spiral staircases, uneven surfaces, and narrow doorways, which create challenges to accessibility. One way that access to these areas can be improved is through telepresence robots. The telepresence robot is a remote-controlled robot that displays a real time image to a screen that the user views at a different location. For example, if there is a visitor that cannot access an area due to a set of stairs but is visiting with their family, the telepresence robot can help the visitor enjoy the exhibition by moving alongside their family. This allows visitors with mobility impairments to continue to experience the Tower at their own pace while interacting with their family. If HRP chooses to implement telepresence robots we recommend the Beam Pro telepresence robot. The robot retails at $13,950 with a $33 monthly fee per robot; the price in British Pounds will vary with conversion rates, currently the robot would cost approximately £9300 with an additional £23 monthly fee. Before HRP implements a telepresence robot we recommend that battery life is carefully considered as well as WiFi strength. The Beam Pro telepresence robot has a run time of eight hours with a charge time of four hours. Telepresence robots could be a great addition to the Tower of London to improve accessibility in the areas that require stairs to access. In the event that the Tower implements telepresence robots we recommend that there be individual robots for each inaccessible area of the Tower for example, one robot for each floor of the White Tower. In the future telepresence robots have the potential to be used with 360-degree video. Virtual Reality headsets could then be used to view exactly what the robot is seeing in a much more immersive way.

5.1.7 Considered technologies

In addition to the recommendations we have already made, there were several technologies that we considered but ultimately decided were unsuitable for implementation at the Tower. One of the technologies we decided was not suitable for implementation at the Tower was 3DS virtual walkthroughs. The 3DS walkthrough offers previews of exhibitions but uses an uncommon technology resulting in minimal adaptability. The Explorer app is very similar to Bluetooth beacons; however, the app itself offers no wayfinding capabilities and is therefore inferior to Righthear. Touch screen displays were also considered but we found that information

could be displayed more effectively through other technologies which would require less physical space in exhibitions, such as Signly. One augmented reality alternative to Signly that we considered was Google glass. We found that Google glass has had very mixed reviews, low resolution, and is unreliable; therefore, we concluded that Google glass would not be suitable for implementation at the Tower of London. One technology that an accompanied visitor recommended to us was a key fob for triggering captions on videos. We believe that key fobs add an extra level of complexity as opposed to displaying captions on videos at all times and would not be beneficial for implementation at the Tower of London. One further technology we found in our research was portable text to speech software. This type of software uses a phone to take a picture of desired text then play an audio version of the displayed information. Through our research and accompanied tours we found that many individuals have experienced reliability and accuracy issues with this type of technology and therefore we do not recommend text to speech software for implementation at the Tower.

5.2 Other recommendations

In addition to the digital technologies that we have recommended to improve accessibility at the Tower of London, we have numerous recommendations of accommodations that HRP could make to improve accessibility that do not involve digital technologies. Although not within the original scope of our project we found that many access challenges have solutions which did not directly pertain to digital technologies. We believe the following recommendations are vital steps that HRP could take to increase accessibility at the Tower.

5.2.1 BSL tours

From our accompanied tour with visitor four we found that there is limited accessibility for D/deaf individuals at the Tower. Currently, the Tower of London offers a BSL tour once a month for D/deaf visitors, but this is very inconvenient for most visitors because they would have to plan their trip up to a month in advance if they want to guarantee a spot in the tour. Due to the lack of accessibility for D/deaf visitors, we recommend that HRP should offer BSL tours more often and that D/deaf tours are added as a tour option. D/deaf tours are BSL tours that are led by a D/deaf person. Offering these tours will improve the experience for D/deaf visitors because communication is complicated if there is an interpreter signing for a Yeoman Warder.

An interpreter also has difficulty conveying the attitude of the Yeoman Warders where a D/deaf tour guide may not. Appendix J lists the comments and observations that visitor four made about D/deaf and BSL tours.

5.2.2 Disability awareness training sessions

From our accompanied tours, we found that it would be beneficial if the staff had more disability awareness training sessions led by individuals with different disabilities. We came to this conclusion because on our accompanied tour with visitor 4, the visitor indicated that the staff needs more D/deaf awareness training. There is no way for a D/deaf individual to communicate with a staff member to ask a question without an interpreter. The visitor had a D/deaf interpreter who lip reads, which the staff was not aware of, so the staff did not look at the interpreter when speaking; therefore, the interpreter could not understand the staff. If the staff had more D/deaf awareness training, they may have been able to recognize that the interpreter was D/deaf and could have inquired about his needs and requirements. Visitor three rented a wheelchair at the welcome desk and needed to take a step-free route around the Tower, yet the staff did not ask about the visitor's access requirements and did not offer the visitor an access guide or a map showing the step-free route. Since the visitor did not know where they could go, they were annoyed because they would walk to places that they later realized they could not access. The visitor's frustration could have been avoided if the staff had more disability awareness training and recognized that visitor four needed the proper information indicating where they could and could not access. Appendices I and J detail the comments that visitors three and four made which led us to recommend more staff disability awareness training sessions.

5.2.3 Remove obstructions from smooth pathways

Our next recommendation is that all garbage cans and other obstructions be cleared off the smooth walkways that are located in between the inner and the outer wall. These smoother walkways are much easier for wheelchair users to navigate compared to the cobbles; however, visitor one was not able to use these pathways because they were obstructed with garbage cans. The inability to use these paths led to visitor one using their wheelchair over the cobbles which they indicated was very uncomfortable. Appendix G shows visitor 1's comments about using their wheelchair over the cobbles. Moving the garbage cans and other obstructions from the

pathways will allow wheelchair users to have a more enjoyable experience at the Tower of London.

5.2.4 Accessible benches

We recommend that more accessible benches be installed at the Tower of London. Accompanied visitor three was not able to sit on a bench when they needed to because the bench height was too low. This was a major issue for this visitor because they had a mobility impairment preventing them from standing for long periods of time, but the benches made it difficult to sit because they may not be able to get back up. Appendix I details the struggles that visitor three encountered on the benches. To rectify this issue, we recommend that some new, taller benches be installed at the Tower so that there is a variety of seating available for visitors.

5.2.5 Contrast on text displays

For all exhibitions there should be better contrast of text on displays. From the accompanied tours we have found that visually impaired and D/deaf or hard of hearing visitors rely heavily on the text in front of all displays, but on a lot of displays the contrast was poor, for example, dark text on a dark background. Many visitors had trouble reading the descriptions, especially in the Crown Jewels since it is such a dark exhibition; therefore, changing the contrast of the text would allow everyone to read the displays and fully experience the exhibition. Visitor five stated that a dark wood background with off white text is the best contrast to use on displays. Appendix K shows all of the comments made by visitor five about the text on displays. Figure 11 shows an image of the best example of contrast of text at the Tower of London.

5.2.6 Lighting on displays

Through multiple accompanied tours we have found that general lighting in all exhibitions poses a challenge for D/deaf and visually impaired visitors. Visitor four is completely D/deaf and communicates solely through BSL, but they said that since it was so dark in the Crown Jewels exhibition, they could not see their interpreter's hands well enough to distinguish what signs the interpreter was using. This made it very hard for visitor four to communicate because they could not properly see what was being said to them. Appendix J shows the comments made by visitor four about the lighting in the Crown Jewels in relation to using BSL.

If the general room lighting in the Crown Jewels could be brighter, without ruining the atmosphere of the room, it would make it easier for D/deaf visitors to communicate as well as make it easier for all visitors to read the text on displays. Visitor five had a hard time seeing the text on displays due to the lighting design. This visitor is visually impaired and legally blind, so they needed to use a magnifying glass and get close to the text to be able to read it. However, since the lighting is directly above the text, when the visitor leaned in to read the caption, they blocked the light with their head which caused the text to be completely dark and unreadable. To fix this issue, visitor five suggested that the lighting should be angled so if they lean in the visitor will still have brightly lit text to read. In addition to changes of the lighting design for displays at the Tower, the descriptions in the display cases should be closer to the front and have a higher contrast so that it is easier to read. For a visually impaired person, such as visitor 5, it is very difficult to read the captions and therefore, the visitor misses out on part of the experience. Appendix K shows visitor 5's recommendations and comments about the lighting and displays at the Tower.

5.2.7 Captions on videos

Visitor two and visitor four emphasized that there should be captions on all videos that are being played around the Tower. For a D/deaf or hard of hearing individual it can be hard to discern what type of sound, if any, is coupled with the video. For this reason, we recommend captions be put on all videos even if there is only music be played or no sound at all. Appendices H and J detail all of the comments made by visitors two and four respectively about putting captions on videos.

5.2.8 Lift entry intercom

When visitor three tried to visit the viewing gallery in the basement of the White Tower, they realized that not only is the lift staff operated, but there is no staff member stationed near the lift. Due to visitor 3's disability, they were reluctant to walk the approximately 50 meters to the closest Yeoman Warder and were forced to walk down the stairs to the gift shop so that they could locate a member of staff to operate the lift. If the visitor had not been accompanied by someone who can use stairs, they would not have been able to access even the basement of the White Tower. We recommend that a buzzer, like the one outside of the Waterloo block offices,

be installed near the lift. A buzzer would allow visitors to contact the control room or a member of staff who could send a nearby warder to operate the lift for the visitor. By allowing the visitor to get help on their own rather than relying on friends or family, the visitor gains an element of independence and convenience that they do not currently have.

5.3 Access information recommendations

Although the access guide and website are not specific digital technologies, updating them has the potential to improve a disabled visitor's experience. Many of the accompanied tour visitors commented on the significance of access information being available online when preparing for a trip to a museum or cultural site. We believe that the following recommendations can greatly improve the quality and availability of access information about the Tower of London.

5.3.1 Access guide recommendations

Historic Royal Palaces has developed a detailed access guide that is available both online on the Tower's accessibility page and in booklet format in the Welcome Center. The guide covers much of the information that a disabled visitor would look for in advance of a visit but due to the difficulty of navigating the visit, some of the visitors we spoke to were unable to find this guide and some instead resorted to websites such as TripAdvisor and google reviews. Additionally, the staff at the Welcome Center indicated that they often receive visitor complaints that the information in the access guide is outdated and inaccurate; they instead try to explain the specific access challenges on the standard map. This unfortunately requires that the visitor ask for the access information and rely on staff when an updated access guide would allow the visitor to be more independent. In regard to the accuracy of the access guide, some visitors commented that the access ratings were too harsh while others thought they were too generous. The idea of rating each exhibition from 1 to 3 is useful but it might be beneficial to have different scores for each area based on specific access challenges rather than the current system of only considering mobility impairments. For example, the White Tower might receive a three for mobility challenges but a one or two for blind visitors and a one or two for D/deaf visitors due to its multimedia and touch displays. This type of system would help summarize the wealth of information currently in the access guide making it easier to understand. Without the visitors

asking, access information was only presented to one of the six accompanied tour visitors. Visitor three checked out a wheelchair from the Welcome Center, but the staff did not give them information on the level access route available at the Tower. Many visitors also do not visit the Welcome Center at the start of their visit and if they do not, they miss the updated information altogether. Finally, the access guide is only available at the Welcome Center and should be available at more places around the Tower. Ideally, it would be available at all information stations and gift shops as well as at the gate where tickets are scanned.

5.3.2 Website recommendations

One of the biggest barriers to access that HRP can quickly address is the difficulty of finding accessibility information on the website. In its current state, the Tower of London website makes it very difficult to find access information for anyone and almost impossible for visitors with learning difficulties or D/deaf visitors who have difficulty with large amounts of text. Ideally, a tab with the word accessibility along with a small BSL interpretation logo should be prominently displayed at the top of the page. This section could also contain the international symbol of access, but the specifics would need to be decided by HRP. Figure 14 shows how this might look. Many disabled visitors may already be anxious about visiting a new historical site and if access information is hard to find, many visitors will be discouraged by the current challenges. The BSL version of the access information should be more prominently displayed on the accessibility page. Some BSL users may be discouraged by the large blocks of text at the top of the page and having that video more readily displayed would help to make these visitors feel more comfortable. A more ambitious goal for improvement to the website would involve dynamic resizing and recoloring options to the page similar to those used on the Graeae Theatre Company's website. Figure 15 shows what these controls look like.

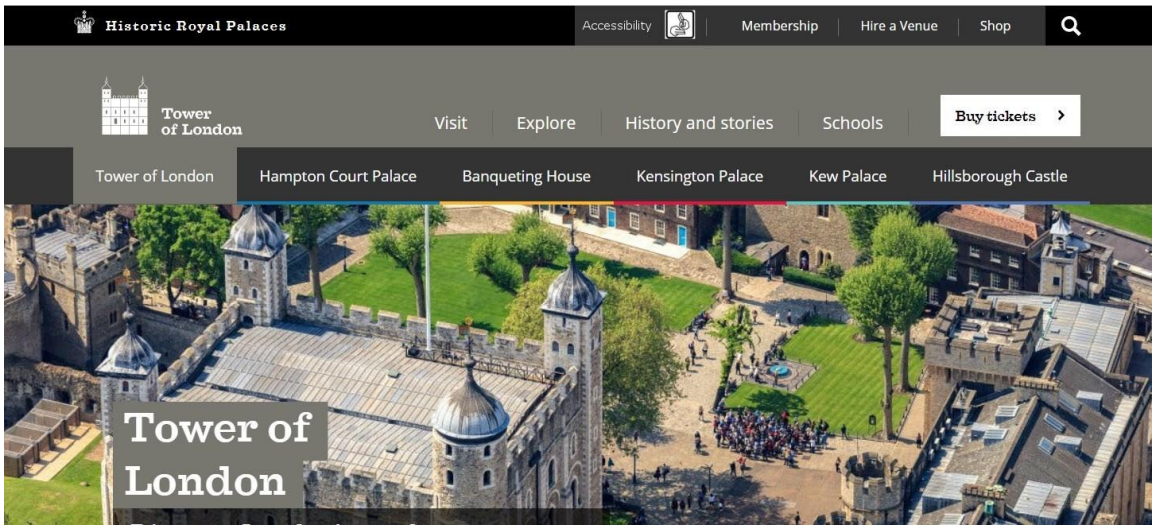

Figure 14: Possible placement for accessibility tab on the Tower website (BSL Courses, 2013)

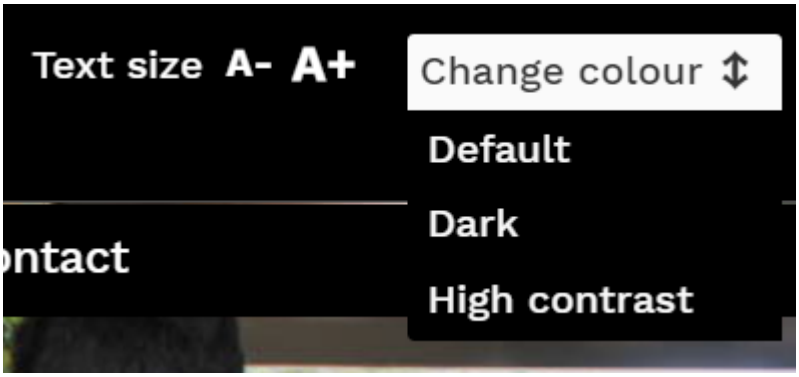

Figure 15: graeae.org accessibility controls

5.3.3 Audio guide improvements

Based on our findings from accompanied tour six, we recommend that HRP reevaluate the accessibility of the audio guide. The new Digital Visitor Guide that is being implemented uses a touch screen and is therefore inaccessible to blind visitors. If a blind visitor wants to use the audio guide, they are given one of the older models. The problem with using the older models arises from the fact that some of these devices, which we saw from accompanied tour six, have a worn-down indicator bump on the number five button so that the visitor was unable to find the correct buttons. There was also no texture on the pause and play buttons, so the visitor could not locate these buttons either. These challenges meant that the visitor relied on us to be able to operate the audio guide. Considering that the audio guide is one of the only

accommodations that the Tower offers for visually impaired visitors, the lack of indicator bumps is a significant barrier to access. We recommend that HRP look into audio guide systems designed specifically for blind or vision impaired users. The British Museum currently uses a smartphone-based system for their traditional BSL and audio guides but has a separate device for the audio descriptive tour with physical buttons. The branding information for these devices is not readily available online so we recommend that HRP discuss the details of this device with the British Museum.

While these improvements do not necessarily fall under the umbrella of digital technology, fixes to the website and access guide could be rapidly implemented and play an important role in a disabled visitor's experience at the Tower of London. Disabled visitors are often very diligent in their pre-visit planning so that they can ensure a pleasant visit for themselves and their family or friends and if the information they need is not available, they may go elsewhere.

6. Conclusion

At the onset of this project, we set out to evaluate how digital technologies can help HRP increase accessibility for D/deaf and disabled visitors at the Tower of London. Over the past 14 weeks we have conducted extensive research into both digital technologies in use at other sites as well as technologies currently under development. Taking into account our knowledge of what is available we then spent extensive time touring the Tower of London and soliciting information from surveys, accompanied tours, and interviews about the current state of access at the Tower. Using this information, we have prepared a report of findings and recommendations of digital technologies for Historic Royal Palaces to consider. This report details technologies that we think will be the most useful for the Tower of London in bridging the access gap for the Tower's disabled visitors. Additionally, we have prepared a list of non-digital solutions to problems that came up in our visits that have relatively low impact implementations.

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Appendices

Appendix A: Sponsor description

Historic Royal Palaces (HRP) was founded in 1998 as a non-profit organization that oversees maintenance and operations at the Tower of London, Hampton Court Palace, the Banqueting House, Kensington Palace, Kew Palace, and Hillsborough Castle (About Us, n.d.; Historic Royal Palaces, 2018). The mission of Historic Royal Palaces is "to help everyone explore the story of how monarchs and people have shaped society, in some of the greatest palaces ever built" (About Us, n.d.). The Tower of London was built as a fortress by William the Conqueror in the 1070s (The story of the Tower of London, n.d.). The official name of the Tower of London is "Her Majesty's Royal Palace and Fortress, The Tower of London" (25 Facts About HM Tower of London, 2013). The Tower of London has been used for a variety of purposes during its long history. Monarchs used the Tower of London as a royal palace, but it also guarded royal possessions and protected the royal family during times of war. The Tower is a symbol of power and fear as a former prison and site of executions for those convicted of treason and other crimes against the crown (The story of the Tower of London, n.d.).

The Tower of London has been a tourist attraction since the 18th century and now attracts approximately 3 million visitors a year. The Tower offers a variety of attractions that range from touring the historic buildings and grounds to exhibitions around the Tower showcasing its use as an armory, prison, palace, and home to the Crown Jewels. HRP entertains visitors with guided tours, reenactments, storytelling activities and special ceremonies, such as the Ceremony of the Keys and the Tower Twilight Tour (The story of the Tower of London, n.d.; Tower Twilight tours, n.d.). The Tower Twilight Tour includes a tour of the Tower of London at night led by Yeoman Warders who tell spooky stories about the history of the Tower (Tower Twilight tours, n.d.). The Tower of London is still, to this day, "home to the Yeoman Warders and their families, the Resident Governor, and a garrison of soldiers" as well as a doctor and chaplain (The story of the Tower of London, n.d.).

HRP receives little funding from the U.K. government and raises most of its funding from visitor admission fees, donors, and sponsors (About Us, n.d.). Since the 2009/10 fiscal year roughly 28% of HRP's annual expenses have been for upkeep and improvements of each palace according to their annual reports as shown in Figure 16. HRP's income is heavily dependent on donors, members, and visitors to their sites. Figure 17 shows the income distribution (Annual

Report 2016/17, 2017). In the 2016-17 fiscal year HRP reported 4.4 million visitors to their properties accounting for 62.5 percent of their income. This is a 12% increase from the 2015-16 fiscal year. HRP's most popular site is the Tower of London which drew 2.8 million guests accounting for 63 percent of HRP's total visitors in the 2016-17 fiscal year as shown in Figure 1 (Annual Review 2016/17, 2017). HRP also offers a membership to guests who feel they will visit frequently. HRP membership has grown in recent years and reached a peak in 2016/17 with 96,000 members. From 2009 to 2014 HRP's annual income has increased significantly each year. However, according to HRP's annual reports their income has leveled out over the past three years at around £90 million per year. Additionally, HRP keeps a £5 million reserve to cover potential shortfalls in visitation and revenue. In 2016 HRP employed 985 employees and relied on 338 volunteers (Charity Commission, U.K. Government, 2017).

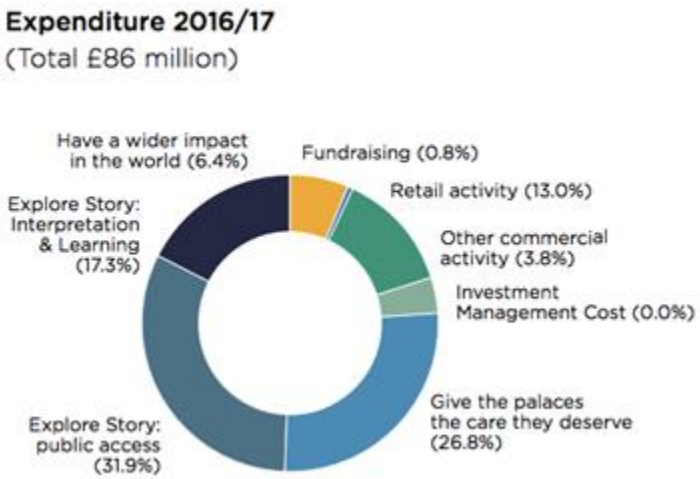

Figure 16: HRP expenditures from 2016-2017 (Annual Report 2016/17, 2017)

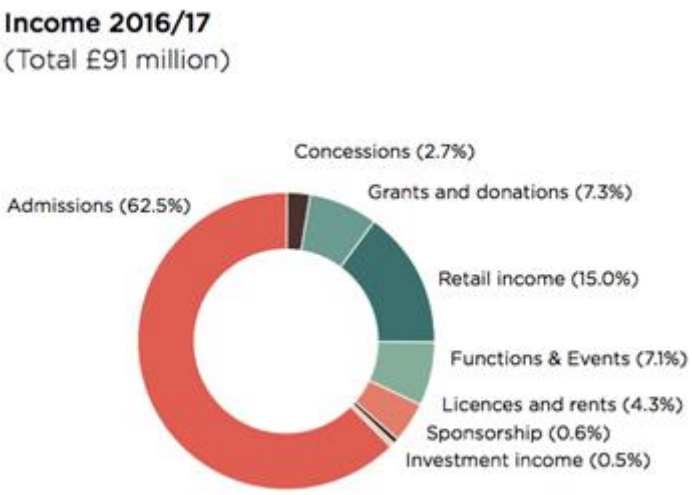

Figure 17: HRP income from 2016-2017 (Annual Report 2016/17, 2017)

HRP is committed to promoting greater access to all its properties, although historic properties present considerable challenges. Many of the traditional methods for increasing accessibility are employed on tours and at exhibits. For the hard of hearing, induction loops are available at ticketing areas and the welcome center in addition to being carried by the Yeoman Warders leading guided tours. This technology allows people with hearing aids to switch to the telecoil setting on their hearing aids which will allow them to hear the tour without having to worry about background noise. Tours given in British Sign Language are also available but only on select dates. For those with limited mobility, the Tower of London offers wheelchairs on site that are available for free with admission as well as a lift which allows visitors to access the White Tower basement and virtual tours of the Medieval Palace and Battlements. For those with limited sight or blindness, descriptive tours are available as an alternative to the standard audio guides if they are scheduled in advance. There are also areas with tactile displays and information in braille in the basement of the White Tower and in the upcoming Armoury in Action exhibit. Additionally, guides for how to best enjoy the Tower when accompanied by an adult or child with autism have been created with the help of the British National Autistic Society (Accessibility, n.d.).

While the Tower of London is currently more accessible than might be expected given the unique challenges involved in increasing accessibility at historic sites, the evolution of technology brings with it an incredible capacity to enhance the experiences for visitors with

various disabilities. The main goal of the Historic Royal Palaces organization is to “help everyone explore the story of how monarchs and people have shaped society, in some of the greatest palaces ever built.” HRP is interested in promoting access and new and emerging technologies may offer innovative approaches. For example, the Augmented Reality Glasses trialled at the National Theater in London could allow disabled visitors to the Tower to enjoy an experience more similar to that had by non-disabled guests with little to no disruption to other guests or employees (About us., n.d.).

Appendix B: Current accessibility technologies

Technology	What it does	Where it is used	Associated costs
3DS Virtual Walkthrough	The Nintendo 3DS Walkthrough allows visitors at the museum to take an audio tour and virtual walkthrough before their visit. Disabled visitors can see exhibits up close that they normally might not be able to. People can use the virtual walkthrough to see exhibits that are usually very crowded and which a visitor in a wheelchair might not be able to see at all. While at the museum, the device can be used like a traditional audio tour with the addition of images. Unfortunately, some users have reported that as the exhibits are moved, the app is not updated. Additionally, the battery life is not long enough for an extended visit and the technology used to locate where the visitor is in the museum can be unreliable (Schramm, 2016).	The Louvre	The Nintendo 3DS Virtual Walkthrough is £124 per device. Users can either use their own device or rent one from the museum.

3D printed relief models of paintings and re-creations of sculptures	Individuals with visual impairments can interact with paintings and sculptures that they are unable to see by using 3D printed models. Paintings can be replicated using either direct line relief or contoured relief. Sculptures can be exactly reproduced by 3D printing. The Belvedere augments these printings with materials used in Klimt's paintings, such as gold leaf for a more immersive understanding of his unique art style (AMBAVis, 2015).	The Belvedere and The British Museum	3D scanners and printers with suitable resolution for museum applications start at £1000 but could be tens of thousands of dollars depending on the device. It is common for museums and historical sites to partner with outside organizations to rent these devices or pay for an outside company to scan and print the artifacts for them.

Signly	When users point the camera of their smartphone at tags placed near exhibits around the museum, Signly allows a video of a sign language interpreter to be overlaid on the camera's video feed. Literacy rates are often much lower amongst individuals with hearing impairments and while many would assume that regular text would be only be an issue for visitors with visual impairments, this is often not the case. Signly allows for a more welcoming and comfortable museum experience for non-hearing visitors (The story of Signly, 2015)	Roald Dahl Museum and Network Rail	The charity, Deafax, created Signly. Pricing information is not available as the application is highly customized for each museum. The organization implementing the service must work closely with Signly to provide relevant info.

Beam Telepresence Robot	The Beam Telepresence Robot allows the user to move a robot around that has multiple integrated cameras and microphones. The robot also has a video display to allow people near the robot to see the operator. The current application of this technology in museums allows visitors who cannot physically travel to each exhibit to experience as much as possible (Kelvey, 2014). A benefit of telepresence over virtual reality or video tours is that the user is able to control their own experience. If a particular exhibit interests them more than others, they can spend more time visiting it and skip over others that are not as interesting. It is as close to actually exploring the museum as is possible for some of its users (Kelly, 2015).	The de Young Museum, Seattle Art Museum, San Diego Museum of Art, Detroit Institute of Arts, San Diego Air and Space Museum, The San Diego Museum of Man, Computer History Museum, and the University of South Dakota's Natural History Museum (Hicks, 2015).	The Beam Telepresence Robot is 5000 USD for the enhanced version and 15000 USD for the pro model.

Appendix C: Emerging technologies

Technology	**What it does**	**Where it is used**	**Associated Costs**
VR Headset Exhibit Recreation at the British Museum	The VR Headset allows visitors to interact with models of particular exhibits and move around between 360 degree photospheres to see historic artifacts in a way that is not normally possible. Visitors can explore from home if they have a virtual reality headset or they can go to a dedicated area at the museum where headsets are available for use ("New Virtual Reality tour of the Museum with Oculus – The British Museum Blog," n.d.).	The British Museum	£115 for the headset plus a compatible phone can be purchased by users or just used on site at the museum. There are additional costs for the museum to scan and photograph various exhibits and artifacts.

Immersive VR tour at the Smithsonian American Art Museum	The Immersive VR tour lets users explore the museum using room-scale VR rather than just photospheres. This project was designed to allow visitors at a satellite location to explore the museum with the highest possible level of immersion. In its current state, this tech is relatively inaccessible due to the difficulty many users with disabilities have with moving around the space (Hardawar, 2017).	Smithsonian American Art Museum	Experimental technology currently. Cost for implementation would be extremely high.

Explorer App at the American Museum of Natural History	The Explorer app was designed to add a level of interactivity to museum exhibits that they did not previously have. The app relies on a network of more than 800 Bluetooth beacons throughout the museum that lets the app pinpoint where the users are and display relevant information. For example, when a visitor is near the museum's blue whale model, they are presented with a size comparison between the whales and subway cars along with audio recordings of some of the sounds the blue whales make. The development team is also working on adding augmented reality experiences to the app in which other information or figures are overlaid on an object viewed through the phone's camera (Erlick, 2017).	American Museum of Natural History	The cost of the explorer app is unknown. The app was custom designed an all the contained activities and supplementary information were put together specifically for use in the app. Additionally, the beacons must be installed and maintained around the museum for the app to work properly.

inFORM Dynamic Display	The inFORM display is a dynamic 3D display created at MIT that allows virtual content to be rapidly and dynamically rendered. Unlike 3D printing, the inFORM display can move and be manipulated which makes it much more flexible. It is limited somewhat by its lower resolution and relatively small interface area but it could potentially make exhibits much more accessible to visitors with vision impairments. (Leithinger, D., Follmer, S., & Ishii, H. ,2013)		Still in development
QR Codes	QR code is invented by Denso Wave in 1994. (History of QR Code | How was the QR Code created? | How has it come to be used so widely? | And what is its future? n.d.) QR codes are a type of barcode that can be scanned by a smartphone and load a webpage, video, or other form of text. QR codes are currently being used in a variety of different settings that range from retailers, to art institutions, to government organizations. (Rosenbloom, 2011)	The Museum of Modern Art	QR codes are free to create and can then be printed wherever needed.

Appendix D: Museum interview

Informed Consent Agreement for Participation in a Research Study

Investigators: Wyatt Bahm, Angel Cao, Marissa Leone, and Andrew Mendizabal

Contact Information: Tower-18D2@wpi.edu

Title of Research Study: Enhancing Access at the Tower

Sponsor: Historic Royal Palaces

Introduction: You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: The goal of this project is to evaluate how digital technologies can help HRP increase accessibility for D/deaf and disabled visitors at the Tower of London and other HRP properties.

Procedures to be followed: The following interview will take approximately 1 hour. The interview will consist of the interviewer, the subject and a scribe. During the interview the subject has no requirement to supply their name to the interviewer. An audio recorder may be used in the event the subject consents to being recorded. The interview may be terminated at any time by request of the subject.

Risks to study participants: There is minimal risk of the potential disclosure of sensitive information about the study participants.

Benefits to research participants and others: The benefit of participating in this interview is that participants have the ability to help improve accessibility at the Tower of London for themselves and individuals with disabilities.

Record keeping and confidentiality: All information from the interview will be kept confidential in Historic Royal Palaces database and WPI's database. Any interview responses may be kept on researcher laptops as well as Historic Royal Palaces database. Records of your participation in this study will be held

confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury: This research will not involve any risk of injury or harm. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:
The Tower of London Project group at Tower-18D2@wpi.edu
Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu
Jon Bartelson, Tel. 508-831-5725, Email: jonb@wpi.edu

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the interview at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

_____ Date: _____

Study Participant Signature

_____

Study Participant Name (Please print)

_____ Date: _____

Signature of Person who explained this study

1. What is your name?
2. Do you mind if we quote you?
3. May we use your name if we quote you?
4. What is the nature of your position at _____?
5. Do you know of any steps has _____ has taken to improve accessibility for individuals with disabilities?
6. What are some of the technologies you currently offer to help the visitors more fully enjoy their visit?
7. What are some of the maintenance considerations of the technologies you have implemented? (example: battery life, reliability, ease of use)
8. Do you know if these accommodations have been well received by the disabled community?
9. Do you find these technologies to be an improvement to the prior technologies in place?
10. Have you received any particularly positive or negative feedback on the accommodations currently in place?
11. Do you know of an assistive technology present at other museums that you wish could be implemented at _____?
12. May we contact you for clarification if need be?
13. Are you aware of any other relevant individuals that we should interview?
14. Are there any other documents or sources that we should review?

Appendix E: Supplemental interview

Informed Consent Agreement for Participation in a Research Study

Investigators: Wyatt Bahm, Angel Cao, Marissa Leone, and Andrew Mendizabal

Contact Information: Tower-18D2@wpi.edu

Title of Research Study: Enhancing Access at the Tower

Sponsor: Historic Royal Palaces

Introduction: You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: The goal of this project is to evaluate how digital technologies can help HRP increase accessibility for D/deaf and disabled visitors at the Tower of London and other HRP properties.

Procedures to be followed: The following interview will take approximately 15 minutes. The interview will consist of the interviewer, the subject and a scribe. During the interview the subject has no requirement to supply their name to the interviewer. An audio recorder may be used in the event the subject consents to being recorded. The interview may be terminated at any time by request of the subject.

Risks to study participants: There is minimal risk of the potential disclosure of sensitive information about the study participants.

Benefits to research participants and others: The benefit of participating in this interview is that participants have the ability to help improve accessibility at the Tower of London for themselves and individuals with disabilities.

Record keeping and confidentiality: All information from the interview will be kept confidential in Historic Royal Palaces database and WPI's database. Any interview responses may be kept on researcher laptops as well as Historic Royal Palaces database. Records of your participation in this study will be held

confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury: This research will not involve any risk of injury or harm. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:
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Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu
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Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the interview at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

_____ Date: _____

Study Participant Signature

_____

Study Participant Name (Please print)

_____ Date: _____

Signature of Person who explained this study

1. What year were you born?
2. What is the nature of your disability?
3. Describe your use of technology in a typical day
4. What types of assistive technologies do you have experience with?
5. Are there any types of assistive technology that you prefer to use?
6. What types of assistive technologies have you had trouble with?
    a. (battery life, difficulty of use, so on)
7. Do you think that digital technology enhances the experience at museums?
8. Have you been to any museums in the part year?
    a. If so which museum(s) and what kinds of assistive technology did they have?
    b. How do you feel the technology could have helped more?
9. Have you visited any HRP locations?
    a. What types of assistive technology were available?
    b. How could the technology have helped more?
    c. Do you feel that there were any exhibits that you were not able to fully enjoy?
10. Did you look for accessibility information for the Tower of London online before your visit?
    a. Was it easy to find?
    b. Was it useful?
    c. Is there any information that you weren't able to find that you would have liked to have known?
11. Do you have any further ideas on how technology can improve accessibility at the Tower of London?

Appendix F: Survey questions

Informed Consent Agreement for Participation in a Research Study

Investigators: Wyatt Bahm, Anqi Cao, Marissa Leone, and Andrew Mendizabal

Contact Information: Tower-18D2@wpi.edu

Title of Research Study: Enhancing Access at the Tower

Sponsor: Historic Royal Palaces

Introduction: You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: The goal of this project is to evaluate how digital technologies can help HRP increase accessibility for D/deaf and disabled visitors at the Tower of London and other HRP properties.

Procedures to be followed: The following survey will be approximately 20 questions. The time to complete this survey will vary from participant to participant. Your name is not required anywhere on this survey however, if you would like to volunteer for an interview there is a section at the end for contact information. All questions of a personal nature are entirely optional and will not affect the subject's ability to submit the survey.

Risks to study participants: There is minimal risk of the potential disclosure of sensitive information about the study participants.

Benefits to research participants and others: The benefit of participating in this survey is that participants have the ability to help improve accessibility at the Tower of London for themselves and individuals with disabilities.

Record keeping and confidentiality: All information from the survey will be kept confidential in Historic Royal Palaces database and WPI's database. Any survey responses may be kept on researcher

laptops as well as Historic Royal Palaces database. Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury: This research will not involve any risk of injury or harm. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:
The Tower of London Project group at Tower-18D2@wpi.edu
Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu
Jon Bartelson, Tel. 508-831-5725, Email: jonb@wpi.edu

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the survey at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By clicking NEXT, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

About You:

1. What year were you born?
    a. (fill in)
2. I identify my gender as __?
    a. Male
    b. Female
    c. Other
    d. Prefer not to specify
3. What access requirements do you have?
    a. Wheelchair access
    b. Step-free access
    c. Bright lighting on displays/written information
    d. Audio amplification
    e. Hearing loop
    f. Quiet spaces
    g. Relaxed environment
    h. High contrast on displays/written information
    i. Large text
    j. Easy Read
    k. Braille
    l. Sign language interpreter
    m. Sighted guide
    n. Audio described tour
    o. Touch tour
    p. Places to sit down throughout the venue
    q. Access for a guide dog/other access dog
    r. Support worker ticket
    s. Accessible toilet facilities
    t. I have no additional access requirement
    u. Other / additional info (short response)

Technology in Your Daily Life:

4. What types of assistive technology (any technology you use to increase accessibility in your day to day life) do you use regularly?
    a. I don't use any assistive technology regularly
    b. I like to use...(short answer)
5. Are there any particular technologies that you actively avoid using and why?
    a. (short answer)
6. Do you know of any types of technology that might help improve accessibility in your daily life? Is there a particular reason you do not use this technology?
    a. (short answer)
7. Which best describes your use of digital technologies (assistive and non-assistive)?
    a. Digital technologies are an essential part of my life
    b. I regularly use digital technologies
    c. I sometimes use digital technologies
    d. I prefer not to use digital technologies
    e. I actively avoid using digital technologies.

Your Use of Technology at Other Cultural and Heritage Sites:

8. How many times have you visited a cultural or heritage site (e.g. art gallery, museum, historic site, theater) in the past year?
    a. 0
    b. 1-5
    c. 6-10
    d. More than 10
9. Which of these cultural and heritage sites were the most accessible and why?
    a. Short answer
10. When planning a trip to a cultural or heritage site do you look for access information online?
    a. Yes
    b. No

11. Are there any digital technologies you have used at the museums or heritage sites you visited in the past year that you think helped improve accessibility?
    a. (Short response)

Visiting the Tower of London

12. Have you visited the Tower of London before?
    a. Yes (Skip have not visited section if possible)
    b. No (Skip to have not visited if possible)

Has Visited:

13. When was the last time you visited the Tower of London?
    a. Less than a year ago
    b. 1 to 5 years ago
    c. 6 to 10 years ago
    d. More than 10 years ago
14. When viewing the accessibility information online, did you encounter any challenges?
    a. (short answer)
    b. Did not view
    c. No challenges
15. What accessibility information (e.g. information to help D/deaf and disabled visitors plan their visit) about the Tower of London would you like to be made available on the website?
    a. (Short response)
16. What kind of assistance, if any, did you receive at the Tower of London?
    a. (short answer)
    b. None
    c. Don't remember
17. Do you feel that you could not experience any parts of the Tower due to a lack of accessibility?
    a. If yes, which parts?
    b. No, accessibility was not an issue for me

18. Do you know of any types of technology that that would have improved your experience at the Tower?
    a. (Short response)
19. Are you aware that you can touch the structure of the Tower of London itself in many places?
    a. Yes
    b. No
20. Have you ever attended a special event (anything other than a standard daytime visit) at the Tower of London and if so, did you feel the the event was fully accessible to you?
    a. Yes
    b. No (why not)
    c. Don't remember

Has not visited:

21. Do you feel that accessibility information about the Tower of London is easy to find online?
    a. Yes
    b. No
    c. I have not tried to view the accessibility information online
22. What accessibility information about the Tower of London would you like to be made available on the website?
    a. (Short response)
23. Are there any challenges interpreting the accessibility information provided online?
    a. Yes, (example)
    b. No
24. Is there an accessibility reason why you have not visited the Tower of London yet?
    a. (short answer)
25. Which parts of the visit would you expect to be the most inaccessible? (include a map)
    a. (short answer)
26. Are you aware that you can touch the structure of the Tower of London itself in many places?

a. Yes
b. No

27. How accessible do you think the Tower of London would be for D/deaf and disabled people?
    a. Completely accessible
    b. Very accessible
    c. Moderately accessible
    d. Not very accessible
    e. Not at all accessible
28. Would you like to receive further information regarding access and inclusion for D/deaf and disabled people at Historic Royal Palaces?
    a. Yes, (email)
    b. No
29. Is there anything else you would like to tell us or think we should know?
    a. (Short answer)

Appendix G: Accompanied tour with a full-time wheelchair user

Visitor 1

Observational notes during the visit:

- The exit from the welcome center had a bump which caused the visitor to be noticeably scared
- Crowded areas were very hard to navigate in a wheelchair, but the warders were helpful in keeping people out of the way and other visitors were very willing to move to the side in the main walkways.
- Cobbles are very bumpy and hard for an electric wheelchair to navigate.
- The visitor noted that there was a sign that said “Crown Jewels this way” but they were going to go another way because the visitor knew the way indicated would not be accessible.
- The visitor said the access guide was outdated and wrong. The visitor noted that it was good that the Tower has it but in its current state it is not helpful.
- When the visitor reached the smoother walkway across from the cafe, they immediately went to it.
- When accessing the Crown Jewels, the visitor needed to go in a separate door that had a slanted walkway which was very far away from the main entrance to the Crown Jewels. Without us guiding her around, they may not have been able to find this wheelchair entrance because you have to know to ask a Yeoman Warder to let you in that way.
- The visitor said that the Jewel House was stressful and hard to navigate due to traffic and the visitor had to wait a while to get close enough to an exhibit to read the description.
- Many people were nice about moving out of the way to allow the wheelchair to pass but others were not as considerate, and they would walk straight past the visitor or would move quickly in front of the visitor to see the exhibit before the visitor could.
- The staff at the Crown Jewels asked the visitor if they wanted to go through the moving walkway and they would stop the other walkway and let the visitor go back the other way to see both sides of it which was very considerate.
- The visitor stated that there should be more dropped kerbs so that the wheelchair can access the smoother cobbles.
- The visitor made full use of the access guide even though it is outdated.

- The visitor noted that if they were to come to the Tower for a full day, they would do the Yeoman Warder tour early to put the layout of the Tower in perspective.
- The Warder tour was shortened due to the rain and only went into the chapel. Because the visitors could not access the chapel, this was very frustrating for them.
- When trying to access the chapel, the visitor asked the warder if there was any way they could see inside the chapel and the warder reluctantly allowed the visitor to view the chapel from the outside. Even though the warders tried to make the chapel accessible to the visitor, it was a very unpleasant experience because it was cold and rainy, and you could not hear what the warders were saying or see the chapel very well. Due to this bad experience, the visitor decided to leave the chapel before the explanation was over.
- The visitor was very happy with the Coins and Kings exhibit because everything was at a good height to allow them to see and read displays. The visitor was especially pleased with the exhibition where a visitor can test the quality of the gold because it was open underneath, so the visitor could roll their wheelchair up to the table so that they could easily touch the metal.
- The visitor noted that the signs around the Tower are useless, especially the step-free access route signs, because it is very unclear where it is leading to or what it means by "step-free access". The step free route signs did not indicate where they were leading and the signs were too high to see the direction properly from the wheelchair.

Notes from the interview (Appendix E shows the full list of questions we asked the visitors in the accompanied tours):

1. The visitor was born in 1983
2. The visitor is a full-time power chair (electric wheelchair) user, step-free, accessible loo.
3. The visitor uses technology daily to find information, communicate, navigate, and find access needs. They use a TV, mobile, and tablet. More likely to use own tech and download an app rather than use an audio guide.
4. Not much assistive technology experience, would use adaptable mouse.
5. Apple touch screen would be easier to use.
6. There were no technologies in particular that the respondent said the actively avoid.

7. Digital technology can enhance experiences at heritage sites and can make them a lot more accessible. Information in a digital format can be easier because signs may be in a bad place. Visitor gets most information about accessibility before entering the venue so digital technology is good because the map is hard to use due to dexterity issues.
8. Visitor has been to approximately 10 museums in the past year. At the imperial war museum, they have interactive technology at accessible heights. The website gives a lot of information about access.
9. Visitor has been to Hampton Court Palace "a long time ago." The visitor was able to use the stair climber there.
10. Visitor looked for information online before arriving. Visitor used TFL route planner to find step-free route and was directed to the Tower of London website to find stations close to the Tower. Visitor researched accessibility information online before the accompanied and researched what other visitors said about access.
11. In actuality the Tower is not accessible. The access guide was useful but if they saw it before coming they may have changed her mind. Crown Jewels: Visitor was happy for the queue jump but also just wanted an equal experience. The film of Queen Elizabeth II's coronation was accessible to the visitor. Chaotic after moving walkway because of the crowd and the visitor cannot see everything. Digital enhancements such as QR codes would help with a video around each exhibit. The Royal Mint: Visitor stated that the exhibition was accessible and could see everything. Digital technology could have help to see things high up. An audio guide could have helped because there is a lot to read. Signage for shops could be better. Yeoman Warder Tour: Visitor felt like the Warders would only give you information if you kept asking. Visitor felt as though they were inconveniencing the Warders. A video or interactive tour of the Tower would help. A 1 to 1 tour with a Warder that is more accessible would help. A video of the inside of the chapel would have improved the tour because the visitor could not enter the chapel. Visitor said using QR codes for wayfinding around the Tower could be helpful. Cobbles are a very serious deterrent to mobility impaired individuals. Interactive person on the HRP website that can speak to individuals looking for access information would be very helpful.

Appendix H: Accompanied tour with a hard of hearing individual

Visitor 2

Observational notes during the visit:

- Andrew had to inform the visitor to put their phone away in the Crown Jewels because the visitor could not hear the warders tell them to put their phone away.
- The visitor said it was hard to understand the map and it did not help them find their way around.
- The visitor tried to follow the signs to the Beauchamp Tower but the signs led the visitor to the chapel. From there, we had to tell the visitor how to get to the Beauchamp execution tower. This shows that the signs are very confusing and sometimes misleading.
- The visitor inquired about BSL tours and how often they were run.
- The visitor cut the visit very short. The visitor only looked at the Crown Jewels and Beauchamp Tower which shows that the visitor must have been frustrated with something at the Tower that made them want to leave.

Notes from the interview (Appendix E shows the full list of questions we asked the visitors in the accompanied tours):

1. 1980
2. D/deaf, hard of hearing, arthritis, fibromyalgia, dyslexia. The visitor has experience using crutches.
3. Uses a laptop daily. Does not use their phone often because it is old.
4. Respondent has experience with a technology where you can go up to an exhibition and scan something to display more information and it also gives a signed description.
5. Virtual sign tour could be helpful because physical BSL tours can be inconvenient. An app to download seems like a good idea but the visitor has an old phone so it may not be possible.
6. Visitor stated that a device you have to hold up to videos to get closed captions are glitchy and unreliable. A device where you can pick what information you would like to know more about or that would provide a BSL video would be very helpful. The visitor states that technology that relies on scanning something such as a QR code is unreliable and should be avoided.

7. The respondent believes that technology can help improve access at museums and cultural sites.
8. This visitor has been to dozens of museums in the past year due to their work.
9. The visitor has not been to any other HRP sites.
10. The visitor did not look for access information online ahead of time because they did not want to skew the results. However, the visitor would normally look for accessibility information online. Some things they looks for in particular are: signed tours, captioned or signed videos, seating access, amount of stairs, technology to replace signed tours, braille, and availability of audio tours. The Visitor stated that anyone with access challenges would look for access information online.

The visitor stated that there was zero signposting around the Tower. Additionally, the maps are hard to understand and difficult to orient. The visitor also stated that there were no sign postings about what you will see in each exhibition or why the items on display are important. The visitor stated that specifically in the Crown Jewels there is nothing to look at for someone who is D/deaf and completely visual. The visitor stated the visit was very frustrating. The lighting in the Jewel House was poor and prevented the visitor from seeing properly. There was feedback in the visitor's hearing aid, so they were forced to turn it off. Subtitles should be put on all videos even if it is just music playing in the background. The visitor stated there is nowhere to sit in the Jewel House for people with mobility impairments. The visitor stated there was nothing in terms of accessibility such as a panel to click for more info. Visitor was very upset that there were no subtitles on any video. The visitor also said that the touch models do not have any braille so blind visitors would not know what object they are feeling.

Appendix I: Accompanied tour with a mobility impaired individual

Visitor 3

Observational notes during the visit:

- Cobblestones are uneven and they restricted the visit.
- All of the maps are far from the main walkway and there is no access information on them.
- The visitor could not see the text descriptions in the Crown Jewels because there were so many people and it was hard for them to get around other visitors.
- There was no place to sit while waiting in line and the visitor could not easily walk around like many others could.
- Without taking a wheelchair along, the visitor would worry about how long the line in the Crown Jewels was. The visitor could not tell how long the line was or if there were any seats ahead.
- The moving walkway in the Crown Jewels was not easy to use for someone with the visitor's specific impairments. Stepping onto a moving walkway can be frightening or impossible depending on the speed of the walkway.
- Overall it is really hard to see in Jewel House since it is very dark so it is hard for mobility impaired individuals to see any level changes or uneven surfaces.
- The visitor commented that for mobility impaired individuals, they would focus more on walking rather than looking at signs.
- The visitor said that the exhibitions are very spread out, which made it hard for them to visit everything.
- The access guide says there is a variety of seating options but almost all benches are the same height and were too low for the visitor to be able to stand back up after they sat down.
- The lift to the basement of the White Tower is staff operated so the visitor must either go down to the gift shop or walk a long distance to the closest warder so they can radio for help. Other staff members direct visitors to the warders but were not able to help. This takes away the independence of the visitor and can in some cases, render the gallery completely inaccessible. It might be useful to have a buzzer like at the entrance to the Waterloo block so that visitors do not have to go searching for staff.

- The visitor found the projector in the basement of the White Tower could be put to much better use, like introducing the rest of the tower that they cannot access.
- Human interaction with the staff added a lot to the visit.
- The visitor cannot keep up with the warder tour and cannot go up the long set of stairs along the route of the tour. There is no offering of the tour that takes a step-free route.
- The Tower's Mint exhibition had very narrow doorways and was difficult to push a wheelchair through. If a wheelchair user was manually operating the wheelchair, their knuckles would likely scrape on the doorframe.
- The visitor expressed that they would be quite annoyed with the Tower's offerings if they had paid for their ticket. They were able to experience only a very small fraction of the Tower but the concession ticket is not discounted accordingly.
- If a visitor could go up and down the small flight of stairs to the chapel but not the long flight of stairs near the White Tower the visitor cannot enter the chapel. The visitor also cannot enter the chapel without being part of a Yeoman Warder tour.

Notes from the interview (Appendix E shows the full list of questions we asked the visitors in the accompanied tours):

1. 1992
2. Mobility Impairment, weak muscles
3. Like most other people, normal technology
4. No
5. Touch screen maybe? The visitor does not like the audio tour in general because it normally takes too long and the visitor has to stand for the duration of it.
6. The visitor stated that they do not use assistive technology often enough to respond.
7. The visitor did not know whether or not digital technology could enhance access at museums or cultural sites.
8. Yes, most of them
9. No
10. The visitor viewed the access page before their visit. They drive everywhere and they will be looking for where they can park their car.

11. The visitor likes the rating on the accessibility guide online and the visitor would be happy if the staff had shown the guide to the visitor before the visit. The visitor also found the telepresence robots very interesting.

Appendix J: Accompanied tour with a D/deaf individual

Visitor 4

Observational notes during the visit:

- The visitor stated that they would never be able to do a Yeoman Warder tour because they cannot hear the warders and the warders do not sign.
- Immediately when you walk into the Tower, there is a sign for audio guide in 11 languages but there is not a BSL option for a language.
- The visitor said that the maps are good because they are completely visual and there is minimal text.
- The visitor has been to the Tower before and did a BSL tour and the visitor said that the warders need to communicate more with interpreters.
- The visitor said there should be a D/deaf tour offered which would be a BSL tour lead by a D/deaf person.
- The visitor said they cannot understand any of the reenactments because there is no sign language and sometimes the visitor does not know who is speaking because the visitor did not see them enter the scene. Additionally, the visitor cannot hear their voice to know in which direction the sound is coming from. Even on the BSL tour days, the Tower does not do the reenactments so the visitor still cannot experience the reenactment.
- The visitor said the staff at the cafe are overworked and pushy and not willing wait for the D/deaf visitor.
- The visitor said that all fire alarms should have flashing lights in case of an emergency.
- The visitor commented on the lighting in general in the Crown Jewels - it is so dark that the visitor would not be able to see someone using BSL to communicate with them. The lighting on all text should be brighter so that individuals can read it clearly.
- The visitor said there should be captions on all videos even if it just says “music” or “no sound”.
- The visitor said that Signly is very good and on all captions there should also be a BSL version offered.
- The visitor said that a key fob that allows the user to activate captions on a video would be very helpful. The visitor saw something similar to this at Disney in America.

- All descriptive tours (audio, BSL, etc.) should be on one device so that a BSL user does not feel like they have something different.
- The visitor said there should be more touch tours around the Tower.
- On the White Tower tour sign, in the Chapel of St. John, the visitor said there should be a sign about how you can inquire to book a BSL tour of that portion of the White Tower.
- The visitor pointed out that in the White Tower, the exhibition of swords has pictures and captions that are very good.

Notes from the interview (Appendix E shows the full list of questions we asked the visitors in the accompanied tours):

1. D/deaf (needed an interpreter)
2. The visitor suggested that a device that could apply to all disabilities at once so that no one feels left out would be best.
3. At the Tate Modern, there is described info for D/deaf visitors specifically that shows D/deaf people signing from the device and you have to key in a number for more info about each exhibition in BSL.
4. The visitor suggested that any person signing in an app (such as Signly) should have a lot of knowledge in the area that they are creating BSL translations of. The signers should be passionate about what they are signing about because there may be specific jargon for each field and only someone who knows a lot about that field would be able to sign properly.
5. A D/deaf tour guide should be used instead of interpreters.
6. The visitor has visited a museum where there was only a BSL translation for a few exhibits, not all of them, so they could only get more information about those specific exhibits.
7. The visitor knew they were missing out on the audio tours when they saw people going around with them and it made the visitor feel left out.
8. The visitor said the staff should be space aware when standing around because they stand in front of exhibits.

9. The visitor said the welcome center is not welcoming and does not know how to deal with a D/deaf person. The visitor said the entire staff needs more D/deaf awareness training that is led by D/deaf people.
10. The visitor said that they are good with understanding maps so the maps were not an issue for the visitor.

The visitor said that a 3D model of a map of the Tower would be very useful.

Appendix K: Accompanied tour with a legally blind individual

Visitor 5

Observational notes during the visit:

- Cobblestones are tough to walk on.
- Lighting differences between the Jewel House and outdoors are hard for the visitor to adjust to.
- The visitor had difficulty finding the doorway and there should be more contrast to indicate where the door located.
- The text on displays are far from the front of the glass case so they were very difficult for the visitor to read.
- The majority of the images on display have very low contrast, no detail, and are very hard to read.
- Lighting design is not ideal. When the visitor tried to get close to read the text, a shadow appeared from their body and blocked the light which made the text dark and completely unreadable.
- For text displays, a dark wooden background with off-white text is ideal.

Notes from the interview (Appendix E shows the full list of questions we asked the visitors in the accompanied tours):

1. 1965
2. Single lens magnifier, Mini Telescope, Indicator cane, legally blind
3. Uses a phone with physical buttons. Touch screens can pose challenges for this visitor due to how close they need to be to read. They also use text to speech software, magnification of screens, and prefer human interactions as opposed to automated systems.
4. Software to magnify screens
5. The user avoids digital technology
6. The visitor avoids bank machines and prefers human interactions. Touch screens can be difficult for this visitor if the wrong button is pressed.
7. The visitor thinks that digital technology can improve the accessibility of museums.
8. The visitor has visited over 30 museums in the past year.

9. The visitor has been to Kensington Palace about a year ago and does not remember using any digital technology during the visit.
10. Yes, but only for a little bit. The respondent does not usually look for accessibility information online.

Thoughts on experience: The visitor had a good experience in general, and they really enjoyed the handling points. The main issues for the visitor were poor lighting design and low text contrast. The visitor also said human interactions are more helpful than digital technology. The visitor wanted more detailed information on displays.

Appendix L: Accompanied tour with a blind individual

Visitor 6

Observational Notes During the Visit:

- The visitor found the Warder tour extremely helpful and interesting. The specific Warder that the visitor had described lots of detail about the buildings and structures throughout the tour, which helped the visitor.
- Wyatt found it hard to hear the Warder when crowds passed and it was hard for the visitor to move through the crowds.
- Wyatt had to show the visitor how the audio tour button works, which should be the staff's job.
- The buttons on the audio guide are not accessible since most of them are very worn down. The visitor said that the buttons should have different textures to indicate different functions.
- The visitor cannot use the audio tour without someone else being there. There was no noise to indicate whether the visitor pressed the button or not. Some button presses did not register and the visitor did not know.
- Wyatt had to tell the visitor which button to press since there was no differences between any of the keys and the numbers in each area are only indicated visually.
- The visitor cannot navigate anywhere without other people because the map is not accessible for blind people.
- The visitor found the audio tour very confusing because it used pictures to orient the user and did not clearly explain where each section started.
- The visitor suggested that the audio tour should also indicate the number of each stop on the specific guided tours so groups can sync up their tours.
- The speakers and background noise in the medieval palace section of the audio tour was difficult to follow.
- The visitor thinks a more specific audio description in the audio tour would help them enjoy their visit more.
- The "excuse me" background voice in the exit of The Tower's Mint was very distracting and confusing.

Notes from the interview (Appendix E shows the full list of questions we asked the visitors in the accompanied tours):

1. The visitor was born in 1962.
2. The visitor is fully blind.
3. The visitor uses email and the internet on a daily basis using the dolphin guide software package. The visitor also uses a cell phone but it is one with buttons, not a smartphone.
4. The visitor only had experience with the technologies that they currently use.
5. The dolphin guide software.
6. The visitor has only had issues using smartphones. The visitor indicated that they think they would be able to master a smooth touch screen but it would take a lot of practice that they have not found the time for.
7. The visitor finds that when implemented correctly, digital technologies do help their experience at museums and give them an extra element of independence rather than having to rely on the people they visit with.
8. The other site that the visitor has gone to in the past year is the Imperial War Museum. They were there as part of a workshop and they did not take the audio guide or use any other accommodations. The visitor does not go to museums often because they have the impression that they are generally not very accessible.
9. The visitor has been to both the Tower of London and Hampton Court Palace before.
    1. Hampton Court Palace offered the visitor no assistive technologies or accommodations.
    2. During the visitor's previous visit to the Tower of London, a member of staff approached the visitor and offered to explain and describe many of the pieces on display as well as provide additional facts and information about various pieces. The visitor described this as an excellent experience.
10. The visitor did not look for access information before this visit but did look before their last visit to the Tower. They indicated that information was difficult to find and based off of our experiences, this is still the case. The visitor speculated that the difficulty of finding this information may be off putting to some and prevent them from trying to visit the Tower.

11. The visitor stated that the ideal way to handle access at museums and cultural sites is to offer a variety of options and technologies so that visitors can use technology that they are familiar with.